A COMPARATIVE ANALYSIS ON THE EFFECT OF PATENT ACTIVITY ON BUSINESS PERFORMANCE IN DIFFERENT FIELDS OF INDUSTRY - AI, BIOTECH, POWER PLANT

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SEMINAR ON INNOVATION AND ENTERPRENEURSHIP

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Summary

The effect of patent activities on the business performance of firms in three different fields of industry was analyzed by exploring the relevant data via multilinear regressions. A research model was established based on previous studies and conceptual reasoning, followed by the construction of hypotheses to be verified. From the database of the USPTO (United States Patent and Trademark Office), 30 companies were selected in three different fields of industry (AI, Biotech, and Power plant) based on the number of patent applications filed spanning from 2013 to 2017 (near the top in each field). These fields were chosen as each of them show some distinctive features in their business operation. The business performance of these three clusters of companies was analyzed using the following variables: the rate of sales increase (per employee), profitability (per employee) and the ratio of R&D expenditure to sales (per employee), in relation to their patent activities. Linear regressions as well as multiple linear regressions (MLR) were performed where the effect of two-way interaction terms was investigated for the latter. It was found that the effect of patent activities on business performance varied depending on the field of industry, which might be a result of the inherent differences in the characteristics of a field in relation to technological innovation. When only the main effects of patent activities were considered in the MLR, the results for the sample of AI companies showed the existence of positive (+) correlations between the number of patents registered per employee and the rate of sales increase per employee, as well as the profitability per employee, and also the ratio of R&D expenditure to sales per employee. In comparison, those of the sample of Biotech firms demonstrated somewhat different results as negative (-) correlations were observed between the number of patents registered per employee and the rate of sales increase (per employee), as well as the ratio of R&D expenditure to sales (per employee). This might reflect the inherent difference between two distinctive industry fields in perspective of technical advancement in relation to the productivity in business operations. Furthermore, it might be worthwhile to note the effect of factored patent indices with similar patterns of movements in the MLR analysis as the limited interaction between explanatory variables tends to deliver somewhat insufficient information in assessing effect of patent activities on business operations.

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`**Table of Contents**

List of Tables ····· **iv**

List of Figures ····· **vii**

Summary ····· **1**

Ⅰ. Introduction ····· **2**

Ⅱ. Previous Studies and Hypothesis Development ····· **4**

1. Patent Rights and Values ····· 4
2. Patent Activity and Business Performance of Firms ····· 5
3. Hypothesis Development ····· 8

Ⅲ. Methodology ····· **10**

1. Research Framework ····· 10
2. Dataset ····· 11

Ⅳ. Data Analysis by Regression and Results ····· **13**

1. Correlation Analysis of Two Variables ····· 13
2. Linear Regressions ····· 17
3. Multilinear Regression (MLR) ····· 22
4. Multilinear Regression with Factor Analysis ····· 39

5. Dummy Variables ····· 45

Ⅴ. Discussion ····· 48

1. Correlation Analysis ····· 48

2. Linear and Multiple Linear Regressions (MLR) ····· 48

3. Linear and Multiple Linear Regressions (MLR) with Factor Analysis ····· 52

4. Limitations of the Research ····· 53

Ⅵ. Conclusions ····· 55

References ····· 59

Appendix ····· 65

List of Tables

Table 3-1 Firms Data Summary ····· 12

Table 4-1 AI Variables Correlation Matrix ····· 14

Table 4-2 Biotech Variables Correlation Matrix ····· 15

Table 4-3 Power plant Variables Correlation Matrix ····· 16

Table 4-4 List of regression variables and corresponding p-values ····· 18

Table 4-5 Rate of sales increase per employee (AI) ····· 23

Table 4-6 Profitability per employee (AI) ····· 23

Table 4-7 Two-way interaction terms ····· 24

Table 4-8 Ratio of R&D expenditure to sales per employee (AI) ····· 25

Table 4-9 Rate of sales increase (Biotech) ····· 26

Table 4-10 Rate of sales increase per employee (Biotech) ····· 27

Table 4-11 Profitability (Biotech) ····· 28

Table 4-12 Profitability per employee (Biotech) ····· 29

Table 4-13 Ratio of R&D expenditure to sales (Biotech) ····· 30

Table 4-14 Ratio of R&D expenditure to sales per employee (Biotech) ····· 31

Table 4-15 Ratio of R&D expenditure to sales per employee (Power plant) ····· 32

Table 4-16 Rate of sales increase (All companies) ····· 33

Table 4-17 Rate of sales increase per employee (All companies) ····· 34

Table 4-18 Profitability (All companies) ····· 35

Table 4-19 Profitability per employee (All companies) ····· 36

Table 4-20 Ratio of R&D expenditure to sales (All companies) ····· 37

Table 4-21 Ratio of R&D expenditure to sales per employee (All companies) ····· 38

Table 4-22 Result of factor analysis for patent indices ····· 39

Table 4-23 Rate of sales increase per employee (AI) ····· 40

Table 4-24 Profitability per employee (AI) ····· 41

Table 4-25 Rate of R&D expenditure to sales per employee (AI) ····· 41

Table 4-26 Rate of sales increase (Biotech) ····· 42

Table 4-27 Ratio of R&D expenditure to sales per employee (Power plant) ····· 42

Table 4-28 Rate of sales increase (All companies) ····· 43

Table 4-29 Rate of sales increase per employee (All companies) ····· 44

Table 4-30 Ratio of R&D expenditure to sales (All companies) ····· 44

Table 4-31 Ratio of R&D expenditure to sales per employee (All companies) ····· 45

Table 4-32 Dummy analysis (Dummy 1: AI=1, Other=0; Dummy 2: Biotech=1, Other=0) · 46

Table 4-33 Dummy analysis (Dummy 1: AI=1, Other=0; Dummy 2: Power plant =1, Other=0) ····· 47

Table 5-1(a) Summary of MLR regression results (without factor analysis): cases identified for interaction effects in conjunction with Table 5-1(b) ····· 49

Table 5-1(b) Summary of MLR regression results (without factor analysis): cases identified to identify the validity of interaction effects …… 50

Table 5-2 Results of the Hypothesis tested …… 51

Table 5-3 Summary of MLR regression results (with factor analysis) …… 52

List of Figures

Fig. 3-1 Research model····· 10

Fig. 4-1 Number of patent applications per employee vs Rate of sales increase per employee 19

Fig. 4-2 Number of patent applications per employee vs Ratio of R&D expenditure to sales per employee ····· 20

Fig. 4-3 Number of patents registered per employee vs Ratio of R&D expenditure to sales per employee····· 21

Fig. 6-1 The effect of patent activity on business performance in different fields····· 56

Summary

The effect of patent activities on the business performance of firms in three different fields of industry was analyzed by exploring the relevant data via multilinear regressions. A research model was established based on previous studies and conceptual reasoning, followed by the construction of hypotheses to be verified. From the database of the USPTO (United States Patent and Trademark Office), 30 companies were selected in three different fields of industry (AI, Biotech, and Power plant) based on the number of patent applications filed spanning from 2013 to 2017 (near the top in each field). These fields were chosen as each of them show some characteristic features in business operation. The business performance of these three clusters of companies was analyzed using the following variables: the rate of sales increase (per employee), profitability (per employee) and the ratio of R&D expenditure to sales (per employee) in relation to their patent activities. Linear regressions as well as multiple linear regressions (MLR) were performed where the effect of two-way interaction terms was investigated for the latter. It was found that the effect of patent activities on business performance varied depending on the field of industry, which might be a result of the inherent differences in the characteristics of a field in relation to technological innovation. When only the main effects of patent activities were considered in the MLR, the results for the sample of AI companies showed the existence of positive (+) correlations between the number of patents registered per employee and the rate of sales increase per employee, as well as the profitability per employee, and also the ratio of R&D expenditure to sales per employee. In comparison, those of the sample of Biotech firms demonstrated somewhat different results as negative (-) correlations were observed between the number of patents registered per employee and the rate of sales increase (per employee), as well as the ratio of R&D expenditure to sales (per employee). This might reflect the inherent difference between two distinctive industry fields in perspective of technical advancement in relation to the productivity in business operations. Furthermore, it might be worthwhile to note the effect of factored patent indices with similar patterns of movements in the MLR analysis as the limited interaction between explanatory variables tends to deliver somewhat insufficient information in assessing effect of patent activities on business operations.

I. Introduction

Patents can be a useful way to measure the technical potential of an entity. In today's world, where the system of patents is globally in use, studying the possible effects they have could help analyze the current trends and influence of innovation. For companies, innovative development of technology and the acquisition of patents is an indispensable factor that influences the entity's competitiveness in the global market. The patent system is, after all, a method for companies to gain recognition and get certified rights for their technology. Thus, one important goal for companies today is to secure patents in patent system of countries around the world, thereby allowing for acquisition in advance of their own technology and the related rights.

The possession of patents by a company is used not only as a method of proving their technologies but also as a legal way for gaining exclusivity in the market. The more technologically advanced a patent is, the higher its value as a company asset. Thus, there have been numerous analyses of the relationship between patents and the innovation and technological advancement of companies. Preexisting studies on the relationship between entities' patent activity and business performance have mainly considered the number of patents simply as a quantitative indicator (Grupp, 1998). However, the technological and/or financial value can differ from patent to patent, so mere quantitative examination of the applications/acceptances of patents may lead to a conclusion that does not reflect the characteristics particular to the firm(s) in question. However, despite the fact that the statistical analysis of patents itself is not a method that allows for deduction of the direct effect of the invention/innovation itself, it is widely used as there is no other sufficient alternative. Yet, due to the characteristic of patents have that a small number of important ones are of exceptionally high value while many of the others are not so valuable, it is difficult to assess/compare the quality of technology by the difference in the number of patents.

The present study has been performed to explore the effect of patent activities on business performance for three different fields of industry (AI, Biotech and Power plant). In order to do this, the patent activity of companies was examined from a quantitative perspective, represented by the

number of applications and the number approved, as well as a qualitative perspective, represented by the value of the patent, and an analysis was carried out on the relationships between these factors and indices of business performance.

Thirty companies in each field were selected from data of the USPTO (United States Patent and Trademark Office) based on the order of the total number of patent applications filed during the period from 2013 to 2017. Five patent indices were defined to measure patent activity and used as independent variables: the patent application ratio, the patent registration ratio, the percentage of accepted patents, the number of patent applications per employee, and the number of patent registrations per employee. Meanwhile, business performance was dealt with using three categorical indices to be used as dependent variables: the rate of sales increase (per employee), profitability (per employee), and the ratio of R&D expenditure to sales. It is hoped that the results obtained through this study will help to understand the relationship between patent activities and the business performance of firms in different fields of industry. Especially, the existence of distinct discrepancies across different fields of industry should be observed in light of understanding the characteristics of a field in its business operation in relation to technological innovation. When only the main effects of patent indices were considered, the cases for the AI and Biotech industries showed somewhat stronger correlations between the patent indices and business indicators. In particular, the latter demonstrated meaningful interrelations between them in all the cases studied, indicating the close relationship of patent activities in relation to the line of products. By contrast, the MLR analysis gave only one case of any meaningful result between patent activity (patent registration ratio) and a business indicator (ratio of R&D expenditure to sales per employee).

This research is organized as follows: Part II consists of previous studies related to this work, and Part III describes the research model and hypotheses of the study. Part IV, which is the core section, shows the statistical analysis on the hypotheses, and in Part V, discussions are carried out using the various results from Part IV. Lastly, in Chapter VI, conclusions and suggestions were made on the basis of the results obtained through this study.

II. Previous Studies

1. Patent Rights and Values

Patent rights have become the most typical and practical means of claiming intellectual property as a part of industrial property. Patent rights give exclusive rights for a technology to the holder, thus securing the profit to be gained from it. Furthermore, by making public the patented technology, technological advancement is catalyzed, and this leads, in turn, to the aim of contributing to industrial development.

The most important reasons for which companies secure patent rights is the fact that a patent gives the holder the exclusive rights in the market for 20 years (differs by country) from the date of patent application, thereby initially prohibiting technological catchup by other entities (Al-Aali et al.., 2013). In addition, a patent can be used as a license, allowing for financial gains from royalty fees (Arora et al., 2006) and opens up possibilities for technical cooperation with other entities using cross-licensing (Di Minin et al., 2013).

Patents can be a useful way to measure the technical potential of an entity. In today's world, where the system of patents is globally in use, studying the possible effects they have could help analyze the current trends and influence of innovation. According to an investigation by Grilches et al. (2006), much previous research has only focused on the number of patents to assess the innovative productivity of companies.

Bloom et al. (2002) asserted their opinion that patent citations are a potentially powerful indicator of technological innovation. They insisted that doubling of the citation-weighted patent stock could result in an increase of total factor productivity by 3%

Zoltan et al. (1988) introduced a more direct measure to explore the relationship between innovation and R&D activities including R&D expenditure and patent inventions. They claimed the difference in the relationships between R&D and innovation and R&D and patents.

The reason that firms expand the scope of their patents by investing to apply for, register, and maintain patents abroad is to dominate international markets by gaining rights to their technology, so a patent that has a patent family is one that is very important to the company.

Patents have both an economically and statistically important impact on firm-level productivity as well as market value. While patenting instantly feeds into market values, its impact on productivity seems to be quite slower (Suziki, 2011).

2. Patent Activity and Business Performance of Firms

The use of intellectual property rights such as patents is closely related to the business strategy and technological innovation strategy of a company in various fields, and effective activity in this regard is a key factor in strengthening the competitiveness, increasing profit, and facilitating diversification of a company.

Previous research on patents and business has focused mainly on fields such as pharmaceuticals, chemistry, machinery, and info-communications where there is a large amount of patent activity. According to a study by Arundel et al. (1998), in the case of large European companies, the field where the patent ratio was highest for new products was the pharmaceutical industry, followed by the office and computer equipment industries. In addition, when Cohen et al. (2000) carried out an investigation on the patent ratio of US companies, the patent ratio of new products was found to be high for the pharmaceutical industry, the medical equipment industry, and the communication equipment industry, compared to other industries. In the case of previous research, also, many studies are done on the pharmaceutical and Biotech industries. The reason for this is that in these cases, most patents each represent one product, and also, because the technology life cycle is relatively long (around 5 or more years), they are suitable for analyzing the influence between patents and business performance.

Wagner et al. (2016) carried out research on data from the pharmaceutical industry in order to find

out whether there is a relationship between patent indices and performance in the product market. In this study, the association between patent indices and 1) the procedure to apply for a patent while the research is yet in an uncertain stage and 2) the procedure where application for a patent is a result of product development. This was to examine the influence of a company's patent activity on the process from the commercialization of a product to it becoming an achievement in the pharmaceutical industry. The results showed that patents accelerated the commercialization process and decreased uncertainty, demonstrating the relationship between patent activity and the stages of product development in the pharmaceutical industry.

In the case of research done by Artz, et al. (2010), 272 companies in 35 industry fields over a period of 19 years were analyzed, and the results showed that patents had a positive correlation with R&D investment, while it had a negative correlation with profitability and sales increase.

Ernst (2001) studied the association between patent applications and the ensuing fluctuations in company performance. His work demonstrated that more national patent applications was associated with an increase in sales with a time-lag of 2 to 3 years following the priority year, whereas European patent applications takes it a little bit longer with a lag of 3 years after the priority year. Generally, the latter are of higher quality than the former and have a higher impact in the market.

Ernst et al. (2016) investigated how patent management and indicators of a firm's financial and patenting performance are associated across multiple industries. Their empirical results demonstrated a positive correlation between two indices of patent management - namely patent protection management and patent information management -- and a company's financial profitability and its patent portfolio's financial and strategic impact. They insisted that there is a strong relationship between patent management and several indices of the performance of a company.

Recently, Ghapar et al. (2014) reported the existence of a notable relationship between patent activity and financial performance on the firm level, where the impact was shown to be rather small and the signs on the coefficients were mixed.

In the work of Andries and Faems (2013), the impact of patent activity on licensing, innovation, and financial performance was studied for both SMEs and large firms. They applied Multiple-group path analyses to a sample of 358 manufacturing firms. Contrary to their expectations, they found that it was not only large firms that benefited from patenting; their research showed that this was also true for SMEs for commercialization of product innovations. Furthermore, for both SMEs and large firms, higher profit margins were observed when there was contribution from such increased innovation performance.

According to the study on the input made by patent-intensive industries to the EU economy (Office for harmonization in the internal market-EU, 2015), large companies were found to be four times more likely to hold patent rights than smaller ones; 40% of larger firms have registered rights, while only 9% of SMEs did. This also demonstrates that those firms holding patent rights are more likely to have better performance compared to those that do not. As SMEs take up an essential part in the EU economy, this is an important finding for the 1.8 million SMEs that hold registered patent rights. It can be seen from the results that those businesses that hold patent rights have higher revenue per employee compared to those that do not, tend to have a higher number of employees, and pay higher wages to their workers. Furthermore, it is clearly visible that this correlation is exceptionally strong for SMEs.

The work of McMillan et al. (2013) explored the part that publishing and patenting activities play as predictors for new product development for a sample of U.S. firms taken from the pharmaceutical industry. In their research, the association between new product development and business performance was also studied. They concluded that, on the whole, publishing and patenting progress are significantly effective predictors of new product development in this industry.

A systematic evaluation on patenting behavior was performed for a sample of 50 business firms in Germany in the mechanical engineering field (1995). Using a framework with multiple patenting indicators, this work pinpointed four different kinds of patenting strategies. Moreover, the association between these strategies and business performance was explored.

Lee et al. (2015) studied patent activities encompassing university-industry collaboration in conjunction with corporate performance. They found the presence of positive effects of patent activities from university-industry collaboration resulting in sales increase in global IT companies.

3. Hypothesis Development

In general, there exists a considerable mutual relationship between patent activity and firms' business performance. Various studies have previously been performed to explore the various issues and arguments arising from their interrelationship from the perspective of technological innovation and corporate planning and management. In their work, Lee et al. (2015) developed nine hypotheses concerning the relationship between firms' patents (internally generated and purchased) and their performance from different perspectives. Their results show that patents are correlated in different ways to firm performance depending on the measure of firm performance considered. Ernst (2001) carried out a similar study where he analyzed 50 German machine tool companies from the point of view of two simple hypotheses. One of them was related to the effect of the quality of patents on firm performance. These led to the development of relevant hypotheses about the relationship between patent indices and business performance indicators in the present work, which is slightly more complex as three different fields of industry are examined simultaneously. Of these, the first is related to identifying the selectiveness of patent indices' correlation to a specific business performance indicator. This is followed by the second hypothesis, which is concerned with identifying the direction of the correlation (positive or negative) that exists between a patent index and a specific business performance indicator. The third and fourth hypotheses were developed in similar contexts by extending the pertinent rationale to reflect the effect when three fields of industry are involved.

According to Art et al. (2010) there is a negative relationship between patent activity and both profitability and sales growth. In their study, they developed a number of hypotheses about the relationship between patent activity and firms' performance in connection with R&D spending. Their analysis, however, covered 272 companies in 35 industries and overlooked distinctive features of

different fields of industry. The fifth hypothesis was developed in the context of exploring the relationship between patent indices and business performance indicators in conjunction with R&D expenditure.

To summarize, five hypotheses were developed, considering the distinctiveness of patent activities with differences in industrial field put into perspective, which were applied to the research model introduced in the beginning of the next chapter.

Hypothesis

H1 Patent activity is correlated with business performance.

1-a: Patent indices will be selectively correlated with a specific business performance indicator regardless of difference in field.

1-b: A patent index correlated with a specific business performance indicator will show the same effect regardless of field difference.

1-c: Patent indices (a patent index) will be positively correlated with a business performance indicator for all of those cases of statistical significance in a specific industrial field.

1-d: A patent index will be positively correlated with a specific business performance indicator regardless of difference in field.

H2 Patent activity is correlated with business performance in relation to R&D productivity.

2-a A patent index correlated with the sales increase (per employee) will be positively correlated with the ratio of R&D expenditure to sales (per employee) regardless of difference in field.

III. Methodology

1. Research Framework

A research model has been established to investigate the relationship between the explanatory and response variables. Here, patent indices are considered as the explanatory (independent) variables whereas measurable indicators of business performance comprise the response (dependent) variables. Fig. 1 shows the concept of the research model which lay the basis of this work to determine the mathematical relationship by statistical methods (linear regression, multiple linear regression). There existed collinearity between some patent indices: between the number of patent applications and the patent application ratio, and between the number of patents registered and the patent registered ratio. This led to the preclusion of the number of patent applications and the number of patents registered in the research model. Additionally, “Profitability” in business performance refers to the ratio of net profit to sales.

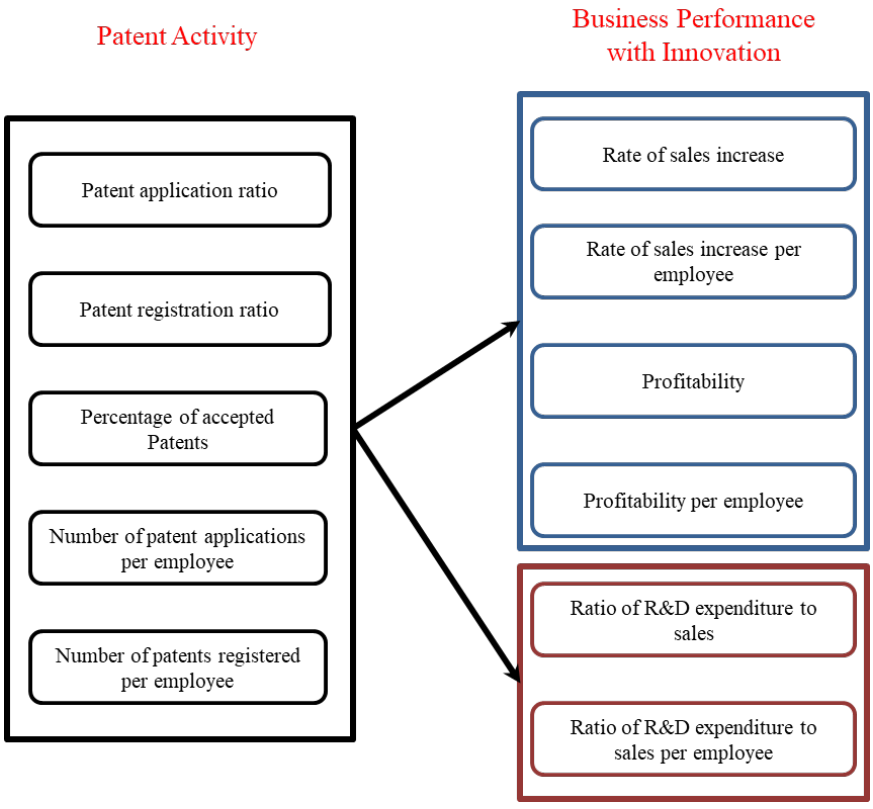

Fig. 3-1 Research model

2. Dataset

From the database of the USPTO (United States Patent and Trademark Office), 30 companies were selected as representative samples for each of the following three different fields of industry – AI, Biotech, and Power plant – based on the number of patent applications filed (near the top in each field), spanning from 2013 to 2017. These fields were chosen as each of them show some distinctive business features in business operation. The chosen fields were selected as each of them shows a distinctive feature when compared to each other in business operations. In the AI field, patent activity is not directly related to production of a tangible product with the application of relevant technologies. The technologies drawn from patents are rather fused into various areas of the firm's operation; inventory management, production-line automation, etc. This field is characterized by high competition, high risks, and a high level of uncertainty, as well as a short technology cycle time (TCT) (Matzler et al., 2009). Here TCT refers to a measure for the time that it takes for a new technology to be replaced by a newer one. In comparison, the Biotech field is characterized by a long TCT (> 5 years) and its patent activity is directly involved with the production of new products to enter the market (Judge et al., 1997). In addition, more revenue is allocated to R&D in this field than in other fields, as shown in Table 3.1. Different from the AI and Biotech fields, the companies in the Power plant field belong to heavy industry, where the outcome of patent activity is rather merged into the development of components of bulky and heavy equipment or machineries. They also tend to rely on the corporation's knowhow (tacit knowledge), which has not been disclosed by patent applications, to a great degree.

Tables 3-1 shows the summary of variables used in the present research drawn from the raw data of patent activities and those of business performance for three different areas of industry. Depending on the field of industry, there exist some distinct discrepancies in the patent data as well as the firm performance data. As aforementioned, the Biotech field appears to locate a greater portion of their sales revenue towards R&D activities as compared to the other fields studied in this work.

Table 3-1 Firms Data Summary

Variable	Mean			Std. Dev.		
	AI	Biotech	Power plant	AI	Biotech	Power plant
Patent application ratio	0.0333333	0.0333333	3.33E-02	0.0748728	0.0477165	0.0504477
Patent registration ratio	0.0333333	0.0333333	0.0333333	0.0798174	0.0718164	0.0382089
Percentage of accepted patents	0.3535339	0.5102491	0.6929825	0.2111868	0.162912	0.161653
Number of patent applications per employee	0.0037856	0.0872483	0.0026172	0.0095169	0.2135846	0.0027141
Number of approved patents per employee	0.001874	0.0560748	1.64E-03	0.0071668	0.1550606	1.57E-03
Rate of sales increase	0.0761807	0.1362091	0.0314294	0.1322927	0.1999488	0.0522235
Rate of sales increase per employee	0.0000141	0.0006155	5.72E-07	0.0000601	0.0025852	1.50E-06
Profitability	0.3383523	0.230635	0.0668268	0.2710842	0.3295183	0.0590573
Profitability per employee	0.0000535	-0.0006648	2.01E-06	0.0002212	0.0038137	4.73E-06
Ratio of R&D expenditure to sales	0.106655	0.292067	0.0454813	0.0687068	0.33992	0.0224477
Ratio of R&D expenditure to sales per employee	0.0000109	0.0014891	1.02E-06	0.0000383	0.0059336	1.19E-06
Variable	Min			Max		
	AI	Biotech	Power plant	AI	Biotech	Power plant
Patent application ratio	0.0037303	0.0018276	0.0024713	0.409539	0.2636019	0.2734334
Patent registration ratio	0.0008961	0.0014602	0.0038829	0.4354839	0.4018009	0.1681601
Percentage of accepted patents	0.0188679	0.1926606	0.3454545	0.8	0.8805333	0.9285714
Number of patent applications per employee	0.000093	0.0006321	0.0001053	0.0518293	1.10883	0.009635
Number of approved patents per employee	0.00000328	0.000339	9.77E-05	0.0396341	0.8316222	0.0058337
Rate of sales increase	-0.1360145	-0.0352035	-0.0984058	0.4127876	0.8811303	0.1518666
Rate of sales increase per employee	-4.51E-06	-1.25E-06	-4.70E-06	0.0003282	0.0141756	3.02E-06
Profitability	-0.0009561	-0.9411713	-0.0633338	0.8543262	0.6789893	0.2127118
Profitability per employee	6.39E-08	-0.0208227	-3.73E-07	0.0012187	0.0010383	2.64E-05
Ratio of R&D expenditure to sales	0.0032503	0.0026648	0.0038509	0.236821	1.514808	0.1066049
Ratio of R&D expenditure to sales per employee	2.07E-08	5.00E-07	4.29E-08	0.0002114	0.0321226	6.17E-06

IV. Data Analysis

1. Correlation Analysis of Two Variables

The correlation coefficient statistically measures the strength of the relationship that exists between the relative movements of two variables. Its value ranges from -1.0 to 1.0. The correlation coefficient provides a valuable piece of information in understanding the effect of one variable on another, which could be effectively used to make predictions without undue difficulties. In this work, correlation coefficients between major variables were statistically measured by running STATA, which gave results in the form of a correlation matrix. Tables 4-1, 4-2 and 4-3 present the correlation matrices for the companies in the AI, Biotech and Power plant fields, respectively. These matrices provide the basic information concerning the existence of a correlation between two variables (input data), which could be used as a diagnostic for advanced analysis. In this work, it was used as a criterion to select those cases to run linear regressions on; the ones chosen had a correlation coefficient greater than 0.5.

Table 4-1 AI Variables Correlation Matrix

	Number of patent applications	Patent application ratio	Number of approved patents	Patent registration ratio	Percentage of accepted patents	Number of patent applications per employee	Number of patents registered per employee	Rate of sales increase	Rate of sales increase per employee	Profitability	Profitability per employee	Ratio of R&D expenditure to sales	Ratio of R&D expenditure to sales per employee
Number of patent applications	1												
Patent application ratio	1	1											
Number of approved patents	0.9796	0.9796	1										
Patent registration ratio	0.9796	0.9796	1	1									
Percentage of accepted patents	-0.1225	-0.1225	0.0144	0.0144	1								
Number of patent applications per employee	0.0096	0.0096	0.0136	0.0136	0.2757	1							
Number of patents registered per employee	-0.0424	-0.0424	-0.0191	-0.0191	0.3668	0.9747	1						
Rate of sales increase	-0.2118	-0.2118	-0.1534	-0.1534	0.1742	0.0589	0.0648	1					
Rate of sales increase per employee	-0.0884	-0.0884	-0.0659	-0.0659	0.3509	0.9537	0.9855	0.1738	1				
Profitability	0.214	0.214	0.1741	0.1741	-0.1883	0.1342	0.0637	0.0865	0.0295	1			
Profitability per employee	-0.0829	-0.0829	-0.0628	-0.0628	0.3556	0.9644	0.9954	0.0662	0.9827	0.0899	1		
Ratio of R&D expenditure to sales	0.0057	0.0057	-0.0541	-0.0541	-0.2336	0.0097	-0.0787	-0.0048	-0.1073	0.5558	-0.0828	1	
Ratio of R&D expenditure to sales per employee	-0.0885	-0.0885	-0.0711	-0.0711	0.3548	0.9725	0.9931	0.0768	0.9835	0.0792	0.9931	-0.0262	1

Table 4-2 Biotech Variables Correlation Matrix

	Number of patent applications	Patent application ratio	Number of approved patents	Patent registration ratio	Percentage of accepted patents	Number of patent applications per employee	Number of patents registered per employee	Rate of sales increase	Rate of sales increase per employee	Profitability	Profitability per employee	Ratio of R&D expenditure to sales	Ratio of R&D expenditure to sales per employee
Number of patent applications	1												
Patent application ratio	1	1											
Number of approved patents	0.9673	0.9673	1										
Patent registration ratio	0.9673	0.9673	1	1									
Percentage of accepted patents	0.2991	0.2991	0.4793	0.4793	1								
Number of patent applications per employee	-0.0787	-0.0787	-0.0216	-0.0216	0.2984	1							
Number of patents registered per employee	-0.0517	-0.0517	0.0066	0.0066	0.3309	0.9895	1						
Rate of sales increase	-0.2552	-0.2552	-0.207	-0.207	-0.0887	0.3442	0.2252	1					
Rate of sales increase per employee	-0.1407	-0.1407	-0.0944	-0.0944	-0.0025	0.3744	0.2637	0.7532	1				
Profitability	0.2324	0.2324	0.2231	0.2231	0.2019	-0.3016	-0.2015	-0.6422	-0.6935	1			
Profitability per employee	0.1174	0.1174	0.0803	0.0803	0.047	-0.2624	-0.1537	-0.6956	-0.9867	0.6894	1		
Ratio of R&D expenditure to sales	-0.2062	-0.2062	-0.1512	-0.1512	0.0197	0.5093	0.4012	0.8717	0.7478	-0.7776	-0.6811	1	
Ratio of R&D expenditure to sales per employee	-0.1456	-0.1456	-0.0964	-0.0964	0.0249	0.4679	0.3643	0.734	0.9927	-0.7001	-0.9731	0.7581	1

Table 4-3 Power plant Variables Correlation Matrix

	Number of patent applications	Patent application ratio	Number of approved patents	Patent registration ratio	Percentage of accepted patents	Number of patent applications per employee	Number of patents registered per employee	Rate of sales increase	Rate of sales increase per employee	Profitability	Profitability per employee	Ratio of R&D expenditure to sales	Ratio of R&D expenditure to sales per employee
Number of patent applications	1												
Patent application ratio	1	1											
Number of approved patents	0.9014	0.9014	1										
Patent registration ratio	0.9014	0.9014	1	1									
Percentage of accepted patents	-0.4312	-0.4312	-0.1784	-0.1784	1								
Number of patent applications per employee	0.4727	0.4727	0.4512	0.4512	-0.4174	1							
Number of patents registered per employee	0.3088	0.3088	0.4042	0.4042	-0.1405	0.931	1						
Rate of sales increase	-0.0968	-0.0968	-0.1254	-0.1254	-0.0477	-0.045	-0.1089	1					
Rate of sales increase per employee	-0.0876	-0.0876	-0.1309	-0.1309	-0.1672	0.1449	0.0299	0.6333	1				
Profitability	0.162	0.162	0.1479	0.1479	-0.1555	0.2541	0.2764	-0.1081	-0.3602	1			
Profitability per employee	-0.1241	-0.1241	-0.1511	-0.1511	0.0632	0.2343	0.3227	-0.2014	-0.5643	0.5309	1		
Ratio of R&D expenditure to sales	-0.0539	-0.0539	-0.0223	-0.0223	-0.006	-0.0353	-0.0408	0.3757	0.0335	-0.1889	0.0023	1	
Ratio of R&D expenditure to sales per employee	-0.2256	-0.2256	-0.2711	-0.2711	0.0257	0.3527	0.4234	-0.0269	-0.2284	0.3505	0.8931	0.1387	1

2. Linear Regressions

One on one linear regressions were carried out for those cases where the correlation coefficient between an explanatory variable (patent index) and a response variable (business indicator) was greater than 0.5, as aforementioned. Table 4-4 is a summary of the linear regressions for the cases considered. As shown, thirteen cases were considered across companies from different industries, including the case where all companies were combined together into one sample (90 companies). Depending on the field, there exist discrepancies as to whether a result presents any statistical significance. This could be identified by checking the corresponding p-values of the regression table. By examining the results of these linear regressions, one could readily predict the influence on the variation of a specific variable even with the involvement of another variable as dealt in multivariable analysis.

Figs. 4-1, 4-2, and 4-3 are the linear regression results for the companies in each field as well as for all companies ignoring the categorical distinction of industry. The presented cases are those where the p-values fall within the acceptable limit of 0.05 for statistical significance. Additional results are given in Appendix A.

Table 4-4 List of regression variables and corresponding p-values

Independent variables	Dependent variables	AI companies	Biotech companies	Power plant companies	All companies data
Percentage of accepted patents	Rate of sales increase per employee	0.0573	0.9896	0.3772	0.9680
Percentage of accepted patents	Profitability	0.3189	0.2846	0.4120	0.0123
Percentage of accepted patents	Profitability per employee	0.0538	0.8054	0.7400	0.7927
Number of patent applications per employee	Rate of sales increase	0.7571	0.0625	0.8133	0.0011
Number of patent applications per employee	Rate of sales increase per employee	0.0000	0.0415	0.4450	0.0001
Number of patent applications per employee	Profitability	0.4794	0.1053	0.1754	0.0916
Number of patent applications per employee	Profitability per employee	0.0000	0.1613	0.2127	0.0056
Number of patent applications per employee	Ratio of R&D expenditure to sales per employee	0.0000	0.0091	0.0559	0.0000
Number of patent applications per employee	Ratio of R&D expenditure to sales	0.9596	0.0040	0.8531	0.0000
Number of patents registered per employee	Rate of sales increase per employee	0.0000	0.1591	0.8753	0.0037
Number of patents registered per employee	Profitability	0.7381	0.2856	0.1392	0.2664
Number of patents registered per employee	Profitability per employee	0.0000	0.4175	0.0820	0.0817
Number of patents registered per employee	Ratio of R&D expenditure to sales per employee	0.0000	0.0478	0.0197	0.0001

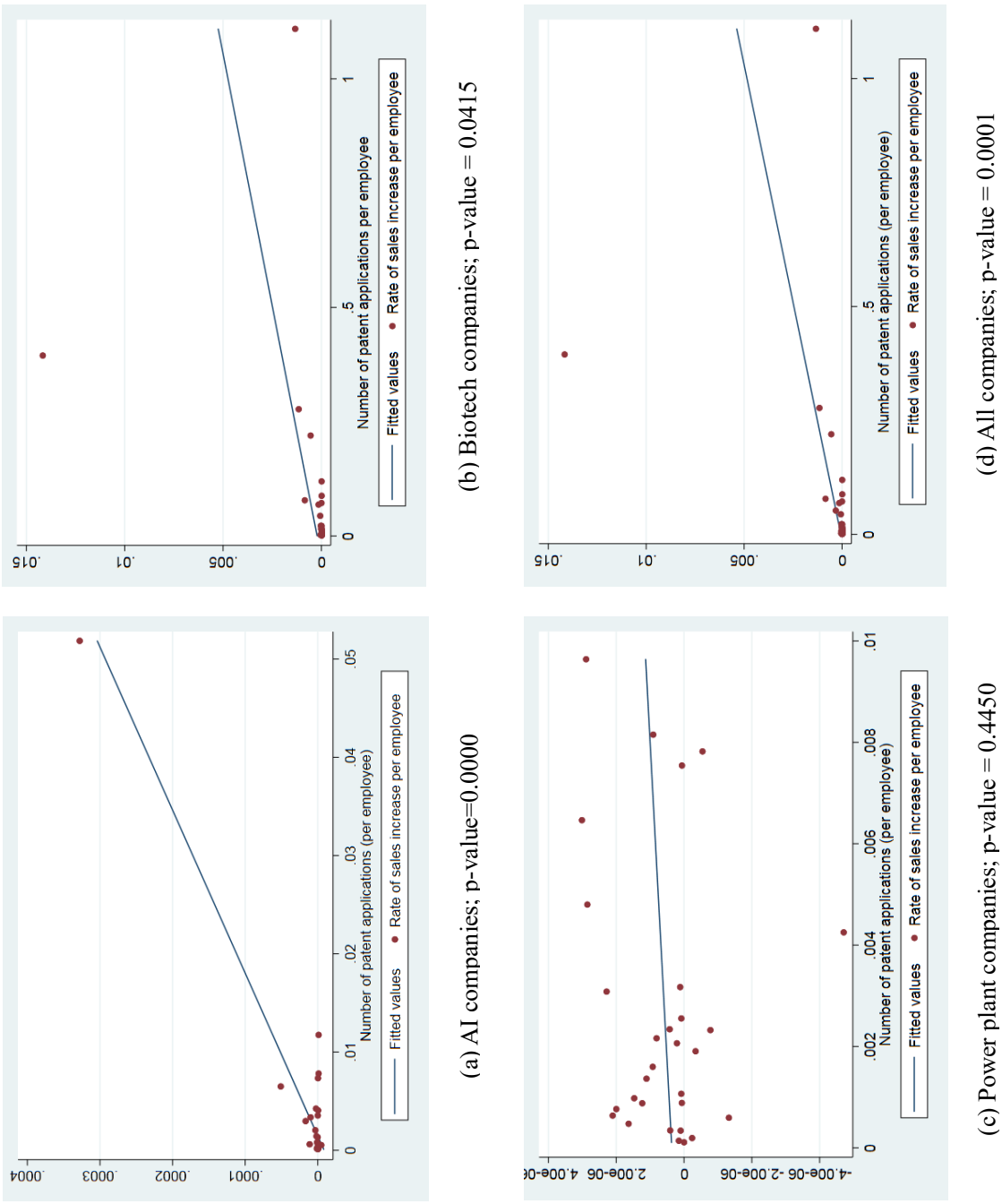

Fig. 4-1 Number of patent applications per employee vs Rate of sales increase per employee

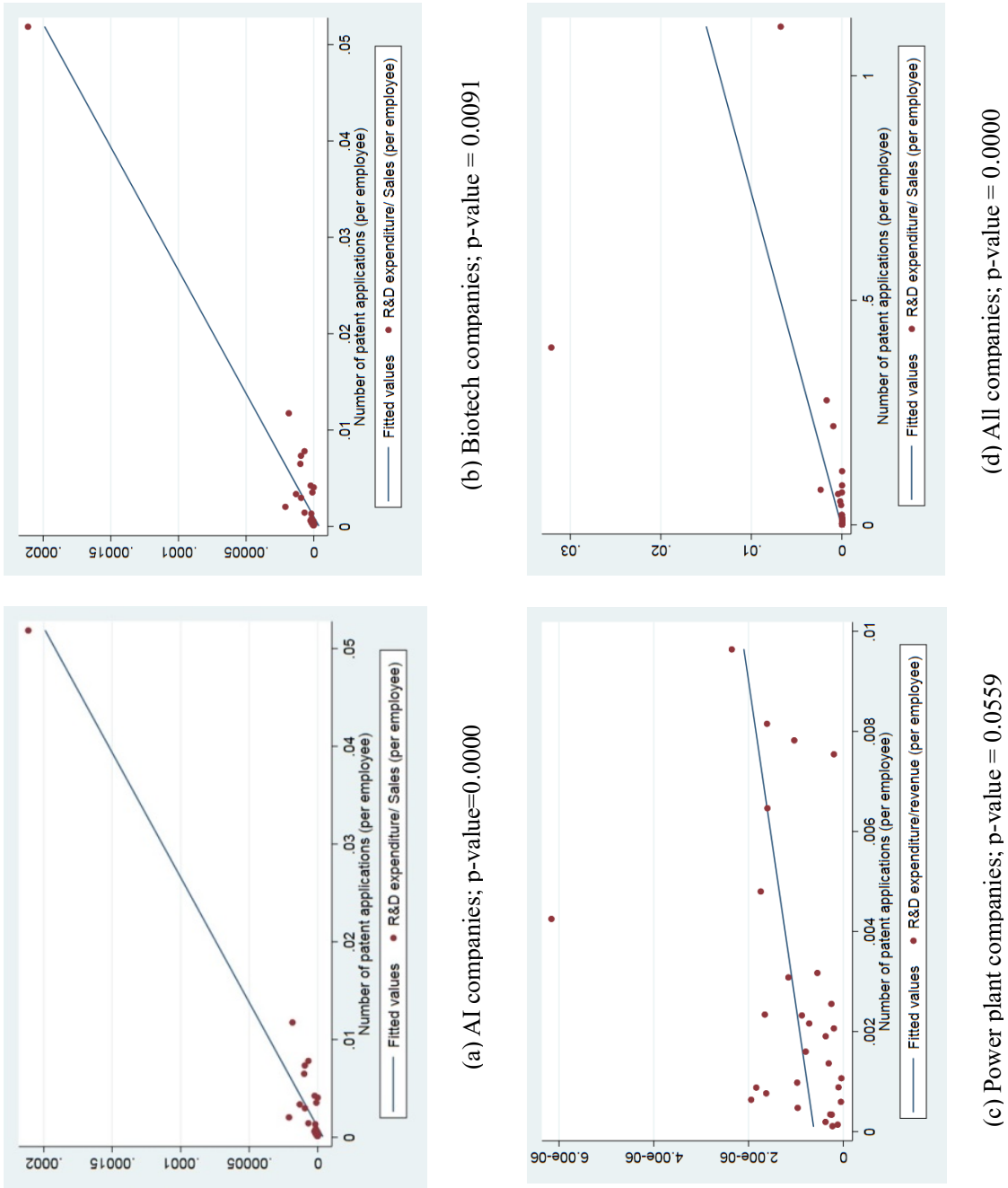

Fig. 4-2 Number of patent applications per employee vs Ratio of R&D expenditure to sales per employee

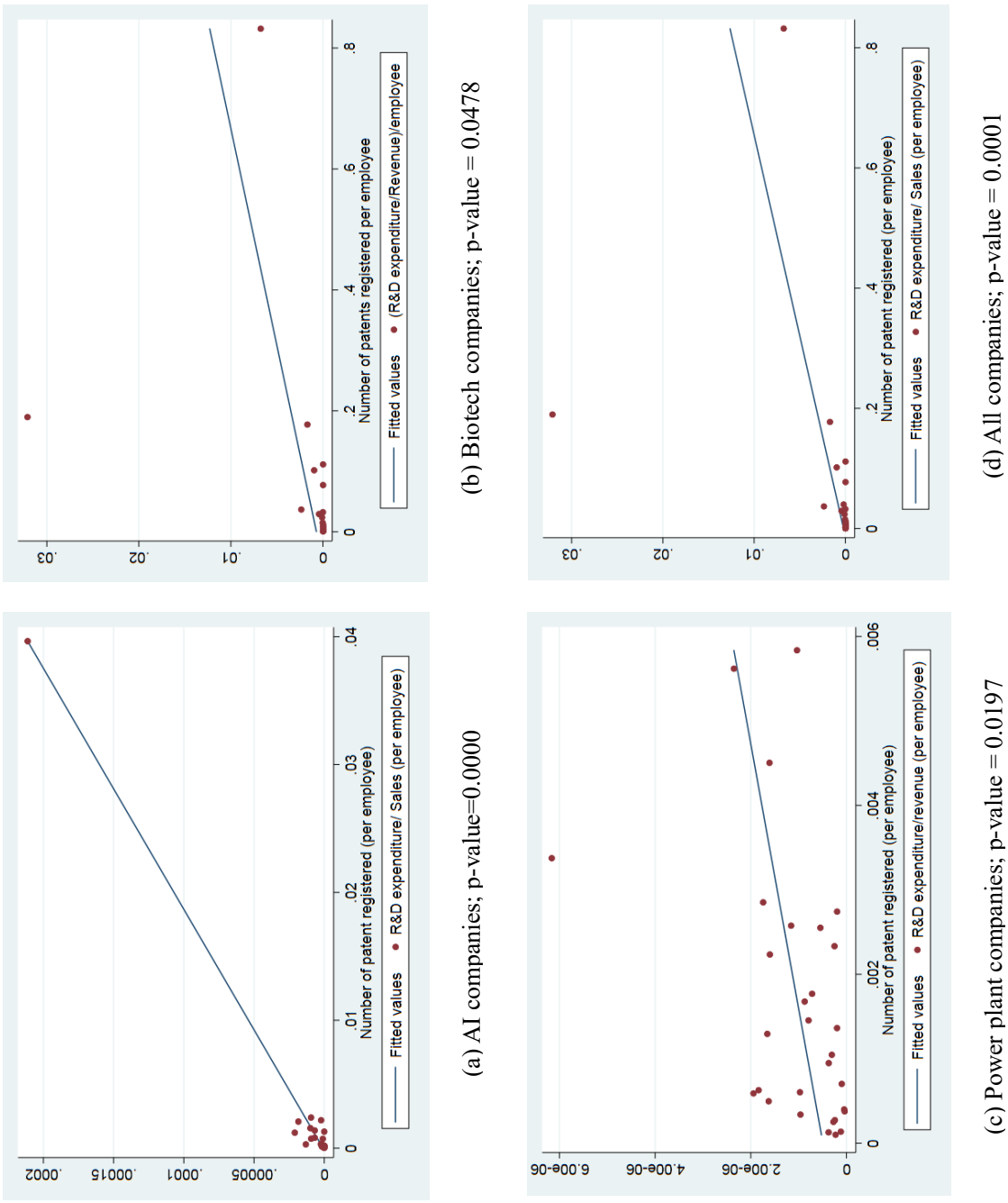

Fig. 4-3 Number of patents registered per employee vs Ratio of R&D expenditure to sales per employee

3. Multilinear Regression (MLR)

Multiple linear regressions (MLR) have been carried out to explore the relationship of a response variable (business indicator) against explanatory variables (patent indices). This is a well-known statistical means to predict the behavior of a response variable with variations in explanatory variables. The eventual goal of the MLRs in this work is to identify (validate) the hypotheses made in the research framework (given it appropriately models the relationship that exists between the explanatory (independent) variables and response (dependent) variables.

3.1 Multiple linear regressions (patent indices vs business parameters)

The results of the MLRs are presented for each of the six business parameters (indicators) against five patent indices. The six business parameters were as follows: rate of sales increase, rate of sales increase per employee, profitability, profitability per employee, ratio of R&D expenditure to sales, and ratio of R&D expenditure to sales per employee. The patent indices comprising the explanatory variables were the following: patent application ratio, patent registration ratio, percentage of accepted patents, number of patent applications per employee, and number of patents registered per employee. Here, the patent application ratio refers to the ratio of the number of patent applications filed by a specific company to the total number of patent applications filed by the thirty companies in the sample of the same field. The patent registration ratio has been defined in a similar way.

3.1.1 AI

Tables 4-5, 4-6, and 4-8 give the summaries of the MLR regression results, where a number of significant statistical indices (p-values, R-squared, root MSE, etc.) are listed. As shown, half of the cases among the six cases considered gave meaningful results conducive to confirming the validity of the hypotheses developed in this work (hypothesis 1-a, 1-c). For these cases, the p-values are highlighted in light green shades. It should be noted that the inclusion of two-way interaction terms slightly improved the R-squared value as compared to when only the main effects of the patent indices were considered in the MLR; the value changed from 0.988 to 0.9907, Table 4-8.

Table 4-5 Rate of sales increase per employee (AI)

Rate of sales increase per employee (Case 1)			
Description	Without Interaction		
	Coefficients	p-value	S.E of Regression
Patent Application Ratio	-0.0000351	0.853	0.0001873
Patent Registration Ratio	0.000000834	0.996	0.0001734
Percentage of Accepted Patents	-0.00000893	0.528	0.000014
Number of Patent Applications per Employee	-9.18E-04	0.391	0.0010511
Number of Patents Registered per Employee	0.0095397	0.000	0.0014274
_cons	0.00000405	0.487	0.00000574
Number of Observations	30		
Sum squared resid	2.6794E-09		
R-Squared	0.9745		
Adjusted R-squared	0.9691		
Root MSE	0.000011		
p-value(F)	0.0000		

Table 4-6 Profitability per employee (AI)

Profitability per employee (Case 1)			
Description	Without Interaction		
	Coefficients	p-value	S.E of Regression
Patent Application Ratio	0.000288	0.405	0.0003398
Patent Registration Ratio	-0.0003725	0.248	0.0003145
Percentage of Accepted Patents	-0.00000979	0.702	0.0000253
Number of Patent Applications per Employee	-3.38E-03	0.089	0.0019069
Number of Patents Registered per Employee	0.0352545	0.000	0.0025894
_cons	0.00000654	0.536	0.0000104
Number of Observations	30		
Sum squared resid	8.8174E-09		
R-Squared	0.9938		
Adjusted R-squared	0.9925		
Root MSE	0.000019		
p-value(F)	0.0000		

The results shown in Table 4-8 involve additional terms to examine the two-way interaction effects between the original variables. The two-way interaction effects were tested in addition to the main effects in the MLR analysis, where applicable. Table 4-7 shows the list of the two-way interactions terms used in the MLR analysis; ai1, ai2, ai3, ai4, ai5……..ai10.

Table 4-7 Two-way interaction terms

Patent Application ratio	Number of patents registered per employee	ai1
Patent Registered Ratio	Number of patents registered per employee	ai2
Percentage of Accepted Patents	Number of patents registered per employee	ai3
Number of Patent Applications per Employee	Number of patents registered per employee	ai4
Patent Registered Ratio	Patent Application ratio	ai5
Percentage of Accepted Patents	Patent Application ratio	ai6
Number of Patent Applications per Employee	Patent Application ratio	ai7
Percentage of Accepted Patents	Patent Registered Ratio	ai8
Number of Patent Applications per Employee	Patent Registered Ratio	ai9
Number of Patent Applications per Employee	Percentage of Accepted Patents	ai10

The above two-way interaction terms constructed from the original explanatory variables (patent indices) could produce an effect that is different from what was observed when only the original explanatory variables were involved in the MLR analysis.

Table 4-8 Ratio of R&D expenditure to sales per employee (AI)

Ratio of R&D expenditure to sales per employee (Case 2)						
Description	Without Interaction			With Interaction		
	Coefficients	p-value	S.E of Regression	Coefficients	p-value	S.E of Regression
Patent Application Ratio	0.000064	0.398	0.0000743	0.0000599	0.45	0.0000779
Patent Registration Ratio	-0.0000857	0.225	0.0000688	-0.0000768	0.31	0.0000739
Percentage of Accepted Patents	0.00000349	0.534	0.00000554	0.00000141	0.777	0.00000493
Number of Patent Applications per Employee	0.0004384	0.304	0.000417	0.0041929	0.005	0.0013524
Number of Patents Registered per Employee	0.0047112	0.000	0.0005663	-0.0206869	0.025	0.0086282
ai1						
ai2						
ai3				0.0395098	0.007	0.0134042
ai4				-0.1868032	0.034	0.0824563
ai5						
ai6						
ai7						
ai8						
ai9						
ai10						
_cons	-1.38E-07	0.952	0.00000228	-2.28E-07	0.911	0.00000203
Number of Observations	30			30		
Sum squared resid	4.2169E-10			2.9966E-10		
R-Squared	0.9901			0.993		
Adjusted R-squared	0.988			0.9907		
Root MSE	0.0000042			0.0000037		
p-value(F)	0.0000			0.0000		

3.1.2 Biotech

Tables 4-9 to 4-14 give the summaries of the MLR regression results for the Biotech companies. As compared to the cases of AI, all cases gave statistically meaningful results only by considering the main effects of the patent indices. The inclusion of two-way interaction effects also produced statistically meaningful results in half of the cases, but these appear to deviate from the (original) research model and add complexity in analyzing the correlation between patent indices and business performance indicators. As shown in Tables 4-10, 4-12, 4-14, the introduction of two-way interaction terms was only effective in boosting the R-squared values.

The results given by Tables 4-9 to 4-14 clearly demonstrate the validity of hypothesis 1-a as different patent indices are correlated to a specific business performance indicator as already shown in the AI cases. Also, as shown in Table 4-14, there exists a negative correlation between the number of patents registered per employee and the ratio of R&D expenditure per employee. This is the opposite of the result shown for the same case in AI (Table 4-11), which negates hypothesis 1-b.

Table 4-9 Rate of sales increase (Biotech)

Rate of sales increase (Case 3)			
Description	Without Interaction		
	Coefficients	p-value	S.E of Regression
Patent Application Ratio	-5.090797	0.035	2.273762
Patent Registration Ratio	3.434153	0.047	1.642348
Percentage of Accepted Patents	-0.2846021	0.176	0.2039517
Number of Patent Applications per Employee	5.18E+00	0.000	0.6159623
Number of Patents Registered per Employee	-6.765492	0.000	0.8572694
_cons	0.2638593	0.037	0.1197856
Number of Observations	30		
Sum squared resid	0.23269042		
R-Squared	0.7993		
Adjusted R-squared	0.7575		
Root MSE	0.09847		
p-value(F)	0.0000		

Table 4-10 Rate of sales increase per employee (Biotech)

Rate of sales increase per employee (Case 2)						
Description	Without Interaction			With Interaction		
	Coefficients	p-value	S.E of Regression	Coefficients	p-value	S.E of Regression
Patent Application Ratio	-0.0440977	0.225	0.0354041	-0.0664889	0.113	0.0399308
Patent Registration Ratio	0.0323652	0.218	0.0255726	0.0894717	0.039	0.0401758
Percentage of Accepted Patents	-0.0018603	0.563	0.0031757	-0.0026544	0.202	0.0020044
Number of Patent Applications per Employee	0.0652808	0.000	0.009591	-0.7622571	0.000	0.1440018
Number of Patents Registered per Employee	-0.0847296	0.000	0.0133483	1.155693	0.000	0.1928623
ai1						
ai2				32.45923	0.002	9.127575
ai3				-2.467339	0.000	0.3934796
ai4				0.087573	0.000	0.0152937
ai5						
ai6						
ai7				21.42666	0.005	6.756756
ai8						
ai9				-42.66788	0.003	12.58363
ai10				1.663532	0.000	0.3021723
_cons	1.01E-03	0.593	0.0018651	1.22E-03	0.28	0.0010921
Number of Observations	30			30		
Sum squared resid	5.64E-05			3.32E-06		
R-Squared	0.7089			0.9821		
Adjusted R-squared	0.6483			0.9712		
Root MSE	0.00153			0.00044		
p-value(F)	0.000			0.000		

Table 4-11 Profitability (Biotech)

Profitability (Case 1)			
Description	Without Interaction		
	Coefficients	p-value	S.E of Regression
Patent Application Ratio	5.605475	0.313	5.434165
Patent Registration Ratio	-3.845715	0.337	3.925119
Percentage of Accepted Patents	0.6377124	0.203	0.4874332
Number of Patent Applications per Employee	-6.95E+00	0.000	1.472115
Number of Patents Registered per Employee	8.921947	0.000	2.048826
_cons	-0.047425	0.87	0.2862809
Number of Observations	30		
Sum squared resid	1.32908872		
R-Squared	0.5779		
Adjusted R-squared	0.49		
Root MSE	0.23533		
p-value(F)	0.0006		

Table 4-12 Profitability per employee (Biotech)

Profitability per employee (Case 2)						
Description	Without Interaction			With Interaction		
	Coefficients	p-value	S.E of Regression	Coefficients	p-value	S.E of Regression
Patent Application Ratio	0.0669617	0.266	0.0588474	0.0978418	0.175	0.0693263
Patent Registration Ratio	-0.0503306	0.248	0.0425057	-0.1367019	0.066	0.0697517
Percentage of Accepted Patents	0.0034893	0.515	0.0052785	0.0037812	0.292	0.00348
Number of Patent Applications per Employee	-0.0934702	0.000	0.0159418	1.157497	0.000	0.2500103
Number of Patents Registered per Employee	0.1236194	0.000	0.0221871	-1.812532	0.000	0.33484
ai1						
ai2				-48.89574	0.006	15.84694
ai3				3.814101	0.000	0.6831438
ai4				-0.1581381	0.000	0.0265524
ai5						
ai6						
ai7				-32.17791	0.013	11.73082
ai8						
ai9				64.15963	0.009	21.8472
ai10				-2.487012	0.000	0.5246198
_cons	-1.78E-03	0.572	0.0031002	-1.67E-03	0.391	0.0018961
Number of Observations	30			30		
Sum squared resid	1.56E-04			1.04E-05		
R-Squared	0.6305			0.9752		
Adjusted R-squared	0.5535			0.9601		
Root MSE	0.00255			0.00076		
p-value(F)	0.0001			0.0000		

Table 4-13 Ratio of R&D expenditure to sales (Biotech)

Ratio of R&D expenditure to sales (Case 3)			
Description	Without Interaction		
	Coefficients	p-value	S.E of Regression
Patent Application Ratio	-6.335762	0.123	3.966079
Patent Registration Ratio	4.339237	0.143	2.864715
Percentage of Accepted Patents	-0.2731155	0.45	0.355749
Number of Patent Applications per Employee	8.35E+00	0.000	1.074411
Number of Patents Registered per Employee	-10.51592	0.000	1.495318
_cons	0.3593922	0.098	0.2089397
Number of Observations	30		
Sum squared resid	0.707964003		
R-Squared	0.7887		
Adjusted R-squared	0.7447		
Root MSE	0.17175		
p-value(F)	0.0000		

Table 4-14 Ratio of R&D expenditure to sales per employee (Biotech)

Ratio of R&D expenditure to sales per employee (Case 2)						
Description	Without Interaction			With Interaction		
	Coefficients	p-value	S.E of Regression	Coefficients	p-value	S.E of Regression
Patent Application Ratio	-0.0987486	0.238	0.0816522	0.1175787	0.075	0.0624035
Patent Registration Ratio	0.0721686	0.233	0.0589777	-0.0522333	0.469	0.0706811
Percentage of Accepted Patents	-0.0046333	0.533	0.007324	0.0019911	0.7	0.0050898
Number of Patent Applications per Employee	0.1413128	0.000	0.0221196	-0.787919	0.01	0.2739608
Number of Patents Registered per Employee	-0.1788411	0.000	0.0307851	1.738835	0.002	0.4837998
ai1						
ai2						
ai3				-3.406897	0.001	0.8865906
ai4				0.209826	0.000	0.0445119
ai5						
ai6						
ai7				-5.883163	0.000	0.7886241
ai8						
ai9				4.676737	0.000	0.8186225
ai10				1.638375	0.004	0.4972943
_cons	2.44E-03	0.576	0.0043016	-2.06E-03	0.45	0.0026678
Number of Observations	30			30		
Sum squared resid	3.00E-04			3.11E-05		
R-Squared	0.7061			0.9696		
Adjusted R-squared	0.6449			0.9536		
Root MSE	0.00354			0.00128		
p-value(F)	0.0000			0.0000		

3.1.3 Power plant

Table 4-15 shows the MLR result of the case involving those companies in the Power plant industry. As shown, only one case presented a meaningful result with statistical significance (Table 4-15) which upholds hypothesis 1-a. As compared to the previous cases of AI and Biotech, the MLR analyses show a rather weak correlation between the patent indices and the business performance indicator. As aforementioned in Chapter III, the companies in the Power plant field belong to heavy industry where the effect of patent activity is rather limited in relation to firms' performance. The relevant patent technologies claimed and put into practice are generally directed to the development of components (parts) of bulky and/or heavy equipment or machineries.

More results are given in Appendix B.

Table 4-15 Ratio of R&D expenditure to sales per employee (Power plant)

Ratio of R&D expenditure to sales per employee (Case 3)			
Description	Without Interaction		
	Coefficients	p-value	S.E of Regression
Patent Application Ratio	0.0000175	0.184	0.0000128
Patent Registration Ratio	-0.0000361	0.027	0.0000153
Percentage of Accepted Patents	0.000000686	0.714	0.00000185
Number of Patent Applications per Employee	-2.15E-04	0.55	0.0003538
Number of Patents Registered per Employee	0.0008542	0.144	0.0005656
_cons	0.000000322	0.813	0.00000134
Number of Observations	30		
Sum squared resid	2.217E-11		
R-Squared	0.4562		
Adjusted R-squared	0.3429		
Root MSE	0.00000096		
p-value(F)	0.0085		

3.1.4 All companies combined

The MLR results when all the companies were considered together regardless of difference in field are given by Tables 4-16 through 4-21. As in the cases of Biotech, all business performance indicators were correlated with patent indices in conformity with hypothesis 1-a. When compared with the cases of AI and Biotech, there exists a negative correlation between the number of patents registered per employee and the ratio of R&D expenditure per employee, similar to the Biotech field. Furthermore, introduction of the interaction effects deems unnecessary as it merely improves R-squared values and draws away from the original research model as observed in the cases of Biotech.

Table 4-16 Rate of sales increase (All companies)

Rate of sales increase (Case 1)			
Description	Without Interaction		
	Coefficients	p-value	S.E of Regression
Patent Application Ratio	-2.62041	0.064	1.394163
Patent Registration Ratio	1.463218	0.21	1.159082
Percentage of Accepted Patents	-0.0409492	0.461	0.0552303
Number of Patent Applications per Employee	5.46E+00	0.000	0.5938859
Number of Patents Registered per Employee	-7.135073	0.000	0.8286443
_cons	0.0866389	0.008	0.032013
Number of Observations	90		
Sum squared resid	0.85594788		
R-Squared	0.5523		
Adjusted R-squared	0.5257		
Root MSE	0.10094		
p-value(F)	0.0000		

Table 4-17 Rate of sales increase per employee (All companies)

Rate of sales increase per employee (Case 2)						
Description	Without Interaction			With Interaction		
	Coefficients	p-value	S.E of Regression	Coefficients	p-value	S.E of Regression
Patent Application Ratio	-0.0127575	0.285	0.0118498	-0.0982095	0.001	0.0285296
Patent Registration Ratio	0.0106297	0.284	0.0098517	0.169228	0.003	0.0544145
Percentage of Accepted Patents	0.0001636	0.728	0.0004694	-0.0003699	0.166	0.0002644
Number of Patent Applications per Employee	0.064379	0.000	0.0050478	-0.2659041	0.000	0.0641765
Number of Patents Registered per Employee	-0.0838981	0.000	0.0070431	0.3879916	0.000	0.0864373
ai1						
ai2				44.40794	0.000	7.362062
ai3				-0.9814121	0.000	0.1780719
ai4				0.0287027	0.000	0.0060268
ai5						
ai6						
ai7				29.46768	0.000	5.827738
ai8				-0.1107258	0.017	0.0454714
ai9				-56.28602	0.000	9.905648
ai10				0.7051472	0.000	0.1339076
_cons	-1.95E-04	0.477	0.0002721	1.78E-04	0.235	0.0001485
Number of Observations	90			90		
Sum squared resid	6.18E-05			1.03E-05		
R-Squared	0.6929			0.9488		
Adjusted R-squared	0.6746			0.9409		
Root MSE	0.00086			0.00037		
p-value(F)	0.0000			0.0000		

Table 4-18 Profitability (All companies)

Profitability (Case 3)			
Description	Without Interaction		
	Coefficients	p-value	S.E of Regression
Patent Application Ratio	-0.4162806	0.896	3.175517
Patent Registration Ratio	1.971701	0.457	2.640068
Percentage of Accepted Patents	-0.4233329	0.001	0.1257994
Number of Patent Applications per Employee	-6.84E+00	0.000	1.352708
Number of Patents Registered per Employee	9.183826	0.000	1.887423
_cons	0.4454232	0	0.0729169
Number of Observations	90		
Sum squared resid	4.44067848		
R-Squared	0.3171		
Adjusted R-squared	0.2765		
Root MSE	0.22992		
p-value(F)	0.0000		

Table 4-19 Profitability per employee (All companies)

Profitability per employee (Case 2)						
Description	Without Interaction			With Interaction		
	Coefficients	p-value	S.E of Regression	Coefficients	p-value	S.E of Regression
Patent Application Ratio	0.0193262	0.327	0.0196185	0.1464946	0.002	0.0456633
Patent Registration Ratio	-0.0175649	0.285	0.0163105	-0.2521593	0.005	0.0870936
Percentage of Accepted Patents	-0.0000865	0.912	0.0007772	0.0005542	0.194	0.0004232
Number of Patent Applications per Employee	-0.0922941	0.000	0.0083571	0.4265503	0.000	0.1027182
	0.1229204	0.000	0.0116606	-0.6906685	0.000	0.1383479
ai1						
ai2				-66.26188	0.000	11.7834
ai3				1.636311	0.000	0.2850143
ai4				-0.0736331	0.000	0.0096462
ai5						
ai6						
ai7				-43.75152	0.000	9.327629
ai8				0.1601397	0.031	0.0727796
ai9				83.66548	0.000	15.85456
ai10				-1.070316	0.000	0.2143267
_cons	2.62E-04	0.562	0.0004505	-2.75E-04	0.252	0.0002376
Number of Observations	90			90		
Sum squared resid	1.69E-04			2.64E-05		
R-Squared	0.6084			0.939		
Adjusted R-squared	0.5851			0.9295		
Root MSE	0.00142			0.00059		
p-value(F)	0.0000			0.0000		

Table 4-20 Ratio of R&D expenditure to sales (All companies)

Ratio of R&D expenditure to sales (Case 2)						
Description	Without Interaction			With Interaction		
	Coefficients	p-value	S.E of Regression	Coefficients	p-value	S.E of Regression
Patent Application Ratio	-2.46844	0.112	1.539055	-1.694085	0.273	1.533796
Patent Registration Ratio	2.037679	0.115	1.279542	1.017317	0.442	1.318276
Percentage of Accepted Patents	-0.10598	0.086	0.0609703	-0.1058531	0.078	0.0593645
Number of Patent Applications per Employee	9.048471	0.000	0.6556069	7.728671	0.000	0.847471
Number of Patents Registered per Employee	-11.33257	0.000	0.9147633	-8.018474	0.000	1.659086
ai1						
ai2						
ai3						
ai4				-1.456803	0.02	0.6152953
ai5						
ai6						
ai7						
ai8						
ai9						
ai10						
_cons	1.50E-01	0	0.0353401	1.46E-01	0	0.0344542
Number of Observations	90			90		
Sum squared resid	1.04E+00			9.77E-01		
R-Squared	0.7678			0.7825		
Adjusted R-squared	0.7539			0.7667		
Root MSE	0.11144			0.1085		
p-value(F)	0.0000			0.0000		

Table 4-21 Ratio of R&D expenditure to sales per employee (All companies)

Ratio of R&D expenditure to sales per employee (Case 2)						
Description	Without Interaction			With Interaction		
	Coefficients	p-value	S.E of Regression	Coefficients	p-value	S.E of Regression
Patent Application Ratio	-0.0264432	0.335	0.0272742	-0.2266248	0.001	0.0633792
Patent Registration Ratio	0.0211138	0.354	0.0226753	0.3948232	0.002	0.1208832
Percentage of Accepted Patents	0.0003064	0.777	0.0010805	-0.000822	0.166	0.0005873
Number of Patent Applications per Employee	0.1392942	0.000	0.0116183	-0.5823266	0.000	0.1425697
Number of Patents Registered per Employee	-0.1772037	0.000	0.0162109	0.8697075	0.000	0.1920226
ai1						
ai2				99.42748	0.000	16.35499
ai3				-2.190855	0.000	0.3955909
ai4				0.0780281	0.000	0.0133886
ai5						
ai6						
ai7				65.69161	0.000	12.94645
ai8				-0.2607383	0.012	0.1010158
ai9				-125.8089	0.000	22.00563
ai10				1.544603	0.000	0.2974787
_cons	-4.28E-04	0.496	0.0006263	3.97E-04	0.232	0.0003298
Number of Observations	90			90		
Sum squared resid	3.28E-04			5.08E-05		
R-Squared	0.6924			0.9523		
Adjusted R-squared	0.6741			0.9448		
Root MSE	0.00197			0.00081		
p-value(F)	0.0000			0.0000		

4. Multilinear Regression with Factor Analysis

4.1 Factor analysis of patent indices

To identify closely interrelated variables and to test them collectively by forming so-called “factors” (groups of collective variables), factor analysis was conducted for patent indices. By performing factor analysis, the patent indices (explanatory variables) were grouped into three distinct factors representative of patent indices with similar patterns of responses observed in the dataset. Each factor formed by conducting factor analysis captures a certain amount of the overall variance in the patent indices, which are listed in order of the amount of variation they explain.

Table 4-22 Result of factor analysis for patent indices

Variables	Factor1	Factor2	Factor3
No of Patent Applications	0.9743	-0.0047	-0.045
Patent Application Ratio	0.976	-0.0154	-0.1678
No of Approved Patents	0.8891	0.0245	0.2865
Patent Registration Ratio	0.9687	-0.002	0.0897
Percentage of accepted patents	0.0165	0.1173	0.6307
Number of patent applications per employee	-0.0075	0.9926	0.0104
Number of approved patents per employee	0.0041	0.9916	0.0502

Table 4.22 shows a result of the factor analysis performed on the patent indices of all companies. Varimax rotation is used to maximize the sum of the variances of the squared loadings. In factor analysis, this is an important second step to clarify the relationship among factors. As can be easily identified, each factor represents a distinctive feature of patent indices grouped together. The first factor (Factor 1) can be interpreted as representing the patent productivity, the second one (Factor 2) as the employee patent productivity, and the last one (Factor 3) as the patent innovativeness.

4.2 Multiple linear regressions

The following are some of the results of the MLR analysis using the factored patent indices drawn from each of the datasets of the AI, Biotech, and Power plant industries, as well as all companies combined. It is worthwhile to note that, as in the corresponding cases without factor analysis, it

deems examining the main effects were enough to identify the correlation between explanatory variables (factored patent indices) and response variables (business performance indicators). Especially, in the AI cases, it was observed that there exists a close similarity between the corresponding cases in such a way that the response variables (business parameters) are correlated with the explanatory variables (patent indices) from the perspective of involving the main effects to produce results of statistical significance. In comparison, the Biotech cases showed no correlation results of statistical significance, which is totally different from those cases without factor analysis. It appears that the factored patent indices fail to carry sufficient information to be correlated with a business performance indicator by the MLR analysis as the factored patent indices are represented by a single number, called a "factor score."

It is also interesting to note the carryover effect of the dominant influence of a specific field into the MLR results of all companies (90 companies) as witnessed by Tables 4-28 to 4-31.

Table 4-23 Rate of sales increase per employee (AI)

Rate of sales increase per employee (Case 3)			
Description	Without Interaction		
	Coefficients	p-value	S.E of Regression
AIP1	-0.00000424	0.076	0.0000023
AIP2	0.0000588	0.000	0.00000232
AIP3	0.00000864	0.001	0.00000232
_cons	1.41E-05	0	0.00000226
Number of Observations	30		
Sum squared resid	3.9751E-09		
R-Squared	0.9621		
Adjusted R-squared	0.9577		
Root MSE	0.000012		
p-value(F)	0.0000		

Table 4-24 Profitability per employee (AI)

Profitability per employee (Case 2)						
Description	Without Interaction			With Interaction		
	Coefficients	p-value	S.E of Regression	Coefficients	p-value	S.E of Regression
AIP1	-0.0000147	0.022	0.000006	-9.10E-06	0.012	3.34E-06
AIP2	0.0002187	0.000	0.00000606	0.0001691	0.000	7.49E-06
AIP3	0.0000292	0.000	0.00000607	0.0000297	0.000	4.41E-06
ai1						
ai2				0.0000684	0.000	9.59E-06
ai3				-0.0000177	0.025	7.44E-06
_cons	5.35E-05	0	5.90E-06	0.0000533	0	3.19E-06
Number of Observations	30			30		
Sum squared resid	2.7173E-08			7.34E-09		
R-Squared	0.9808			0.9948		
Adjusted R-squared	0.9786			0.9938		
Root MSE	0.000032			1.70E-05		
p-value(F)	0.0000			0.0000		

Table 4-25 Rate of R&D expenditure to sales per employee (AI)

Ratio of R&D expenditure to sales per employee (Case 2)						
Description	Without Interaction			With Interaction		
	Coefficients	p-value	S.E of Regression	Coefficients	p-value	S.E of Regression
AIP1	-0.00000282	0.004	0.000000908	-2.37E-06	0.005	7.64E-07
AIP2	0.000038	0.000	0.000000916	0.0000325	0.000	1.73E-06
AIP3	0.00000429	0.000	0.000000918	0.00000362	0.000	7.85E-07
ai1						
ai2				0.00000781	0.001	2.19E-06
ai3						
_cons	1.09E-05	0	8.92E-07	0.0000108	0	7.41E-07
Number of Observations	30			30		
Sum squared resid	6.21E-10			4.11E-10		
R-Squared	0.9854			0.9903		
Adjusted R-squared	0.9837			0.9888		
Root MSE	0.0000049			4.10E-06		
p-value(F)	0.0000			0.0000		

Table 4-26 Rate of sales increase (Biotech)

Rate of sales increase (Case 4)						
Description	Without Interaction			With Interaction		
	Coefficients	p-value	S.E of Regression	Coefficients	p-value	S.E of Regression
BTP1	-0.0457607	0.222	0.036568	-2.33E-01	0.008	8.04E-02
BTP2	0.0560512	0.139	0.0367512	0.2220999	0.000	5.45E-02
BTP3	-0.0035411	0.924	0.0368226	-0.2096912	0.002	5.86E-02
ai1						
ai2				-0.6275612	0.001	0.1677102
ai3				0.1612382	0.007	0.054851
_cons	1.36E-01	0.001	0.0359501	0.13786	0	2.78E-02
Number of Observations	30			30		
Sum squared resid	1.01E+00			5.58E-01		
R-Squared	0.1305			0.5186		
Adjusted R-squared	0.0302			0.4183		
Root MSE	0.19691			1.52E-01		
p-value(F)	0.2952			0.0023		

Table 4-27 Ratio of R&D expenditure to sales per employee (Power plant)

Ratio of R&D expenditure to sales per employee (Case 1)			
Description	Without Interaction		
	Coefficients	p-value	S.E of Regression
PPP1	-4.39E-07	0.025	0.000000184
PPP2	0.000000587	0.004	0.000000186
PPP3	2.86E-09	0.988	0.000000193
_cons	1.02E-06	0	0.000000181
Number of Observations	30		
Sum squared resid	2.5502E-11		
R-Squared	0.3744		
Adjusted R-squared	0.3022		
Root MSE	0.00000099		
p-value(F)	0.0061		

Table 4-28 Rate of sales increase (All companies)

Rate of sales increase (Case 2)						
Description	Without Interaction			Without Interaction		
	Coefficients	p-value	S.E of Regression	Coefficients	p-value	S.E of Regression
P1	-0.024531	0.102	0.0148598	3.14E-02	0.08	1.77E-02
P2	0.0432362	0.005	0.0149337	0.0487257	0.000	1.34E-02
P3	-0.0064331	0.67	0.0150378	0.0009656	0.943	1.35E-02
ai1						
ai2				-0.2760183	0.000	0.0578524
ai3						
_cons	8.13E-02	0	0.0147768	0.0816007	0	1.32E-02
Number of Observations	90			90		
Sum squared resid	1.69E+00			1.33E+00		
R-Squared	0.116			0.3028		
Adjusted R-squared	0.0852			0.2699		
Root MSE	0.14018			1.25E-01		
p-value(F)	0.0137			0.0000		

Table 4-29 Rate of sales increase per employee (All companies)

Rate of sales increase per employee (Case 2)						
Description	Without Interaction			Without Interaction		
	Coefficients	p-value	S.E of Regression	Coefficients	p-value	S.E of Regression
P1	-0.0000924	0.541	0.0001507	5.26E-04	0.000	1.25E-04
P2	0.0005408	0.001	0.0001514	0.0005798	0.000	9.00E-05
P3	-0.0001088	0.477	0.0001525	-0.0011468	0.000	2.05E-04
ai1						
ai2				-0.0050438	0.000	0.0004047
ai3				0.0003069	0.000	0.000049
_cons	2.10E-04	0.164	0.0001498	0.0002158	0.017	8.84E-05
Number of Observations	90			90		
Sum squared resid	1.74E-04			5.91E-05		
R-Squared	0.1368			0.7066		
Adjusted R-squared	0.1067			0.6891		
Root MSE	0.00142			8.40E-04		
p-value(F)	0.0053			0.0000		

Table 4-30 Ratio of R&D expenditure to sales (All companies)

Ratio of R&D expenditure to sales (Case 2)						
Description	Without Interaction			Without Interaction		
	Coefficients	p-value	S.E of Regression	Coefficients	p-value	S.E of Regression
P1	-0.0154037	0.457	0.0206009	3.24E-02	0.131	2.12E-02
P2	0.1156375	0.000	0.0207035	0.1169253	0.000	1.52E-02
P3	-0.0226066	0.281	0.0208478	-0.1915523	0.000	3.48E-02
ai1						
ai2				-0.5475956	0.000	0.0685249
ai3				0.0480316	0.000	0.0082999
_cons	1.48E-01	0	2.05E-02	0.1486804	0	1.50E-02
Number of Observations		90			90	
Sum squared resid		3.25E+00			1.69E+00	
R-Squared		0.2768			0.6228	
Adjusted R-squared		0.2516			0.6004	
Root MSE		0.19435			1.42E-01	
p-value(F)		0.0000			0.0000	

Table 4-31 Ratio of R&D expenditure to sales per employee (All companies)

Ratio of R&D expenditure to sales per employee(Case 2)						
Description	Without Interaction			Without Interaction		
	Coefficients	p-value	S.E of Regression	Coefficients	p-value	S.E of Regression
P1	-0.000215	0.518	0.0003312	1.13E-03	0.000	2.84E-04
P2	0.0015674	0.000	0.0003328	0.0016531	0.000	2.03E-04
P3	-0.0002439	0.469	0.0003351	-0.0024685	0.000	4.64E-04
ai1						
ai2				-0.0109299	0.000	0.0009148
ai3				0.0006585	0.000	0.0001108
_cons	5.00E-04	0.132	3.29E-04	0.0005128	0.012	2.00E-04
Number of Observations		90			90	
Sum squared resid		8.39E-04			3.02E-04	
R-Squared		0.2119			0.7165	
Adjusted R-squared		0.1844			0.6996	
Root MSE		0.00312			1.90E-03	
p-value(F)		0.0001			0.0000	

5. Dummy Variables

To identify the categorical distinction between the datasets used in this work, MLR analyses have been carried out with the inclusion of two dummy variables. The following tables were generated by such analyses (applied to Ratio of R&D expenditure to sale), where the datasets of all companies were used by assigning either 1 or 0 to two dummy variables. As shown in the following tables, some meaningful results of statistical significance were obtained. Table 4-32 was obtained when the first dummy variable (dummy 1) was defined as AI =1 and others = 0 (other remaining fields) while the second dummy variable (dummy 2) was defined as Biotech =1 and others = 0 (other remaining fields).

Meanwhile, Table 4-33 shows the results for when the first dummy variable (dummy 1) was defined as AI =1 and others = 0 (other remaining fields) while the second dummy variable (dummy 2) was defined as Power plant =1 and others = 0 (other remaining fields).

These results indicate that there exists a categorical distinction among the fields considered in this work; AI, Biotech, and Power plant.

Table 4-32 Dummy analysis (Dummy 1: AI=1, Other=0; Dummy 2: Biotech=1, Other=0)

D2_Dummy1: AI=1, Other=0; D2_Dummy2: BIO=1, Other=0

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	D2_Dummy 2, P1, P3, P5, D2_Dummy 1, P2, P4b	.	Enter

a. Dependent Variable: Q7

b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics	
					R Square Change	F Change
1	.892[a]	0.796	0.779	0.105595201	0.796	45.831

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.577	7	0.511	45.831	.000[b]
	Residual	0.914	82	0.011		
	Total	4.492	89			

a. Dependent Varable: Q7

b. Predictors: (Constant), D2_Dummy2, P1, P3, P5, D2_Dummy1, P2, P4

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics
		B	Std. Error	Beta			Tolerance
1	(Constant)	0.061	0.056		1.093	0.278	
	D2_Dummy 1	0.049	0.036	0.104	1.373	0.173	0.057
	D2_Dummy 2	0.107	0.032	0.226	3.317	0.001	0.058
	P1	-1.711	1.502	-0.14	-1.139	0.258	0.346
	P2	0	0	0.118	0.931	0.355	0.018
	P3	-0.023	0.075	-0.023	-0.309	0.758	0.018
	P4	8.572	0.646	4.899	13.274	0	0.37
	P5	-10.812	0.892	-4.441	-12.117	0	0.558

Table 4 - 33 Dummy analysis (Dummy 1: AI=1, Other=0; Dummy 2: Power plant =1, Other=0)

D3_Dummy1: AI=1, Other=0; D3_Dummy2: PP=1, Other=0

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	D3_Dummy 2, P2, P5, D3_Dummy 1, P3, P1, P4b	.	Enter

a. Dependent Variable: Q7

b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics	
					R Square Change	F Change
1	.892[a]	0.796	0.779	0.105595201	0.796	45.831

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.577	7	0.511	45.831	.000[b]
	Residual	0.914	82	0.011		
	Total	4.492	89			

a. Dependent Varable: Q7

b. Predictors: (Constant), D3_Dummy2, P2, P5, D3_Dummy1, P3, P1, P4

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics
		B	Std. Error	Beta			Tolerance
1	(Constant)	0.168	0.045		3.747	0	
	D3_Dummy 1	-0.058	0.031	-0.122	-1.865	0.066	0.057
	D3_Dummy 2	-0.107	0.032	-0.226	-3.317	0.001	0.058
	P1	-1.711	1.502	-0.14	-1.139	0.258	0.346
	P2	0	0	0.118	0.931	0.355	0.018
	P3	-0.023	0.075	-0.023	-0.309	0.758	0.018
	P4	8.572	0.646	4.899	13.274	0	0.534
	P5	-10.812	0.892	-4.441	-12.117	0	0.558

V. Discussion

As can be seen in the details of the methods of analysis as well as the corresponding results given in the previous chapter, this work has been carried out largely in three steps for its study by statistical analysis; correlation analysis between variables, linear and multiple linear regressions (MLR), and linear and multiple linear regressions (MLR) with factor analysis.

1. Correlation Analysis

As previously mentioned in Chapter IV, this statistically gives the strength of the relationship of two variables in conjunction with their movements as observed in a dataset. The correlation coefficient could be used effectively to deduce the effect of one variable onto another and to explore the conceptual reasoning in understanding the relationship that exists between them. The correlation matrices, summarizing the correlation coefficients between two variables, provided the initial intuitive understanding concerning the variation of variables as they are given in a dataset. The criterion used – to select those cases with the correlation coefficient greater than 0.5 – deems to be reasonable judging from the results obtained in the linear regressions as well as the multiple linear regressions as presented in Chapter IV.

2. Linear and Multiple Linear Regressions (MLR)

2.1. Linear regressions

The linear regression results demonstrated the existence of differences across the field which demonstrate any meaningful statistical significance ($p < 0.5$). It was observed that six cases in AI fall within the criterion, whereas four cases in Biotech and one case in the Power plant industry satisfy the criterion. When all cases are considered at once (90 companies data considered at once ignoring the field differences), it was found that eight cases are to be considered. Of the eight cases, there were three where the p-values were lower than 0.05 in both AI and Biotech. In addition, there were three additional cases where p-values were lower than 0.05 in AI only. This might be suggesting that the prevailing effect of a field (or two fields) is sustained even after all companies are considered

together, and the blending of the remaining data set was not enough to overcome the effect carried over. It appears that the statistical outcome of the linear regressions was carried over even when additional variables were introduced in the analysis to identify the effect of explanatory variables onto a response variable, as witnessed in the MLR analysis discussed below.

2.2. Multiple Linear Regressions (MLR)

As given in Chapter IV, concerning the detailed data analyses of the MLR and their results, there were distinctive discrepancies observed across different fields among variables as to the effect of patent indices onto a business parameter. Table 5-1 (a) gives a summary of the MLR results performed in this work for the companies in three different fields of industry (AI, Biotech, Power plant) and for all companies combined. Here, in Table 5-1 (b), M stands for the case when only the main effects were considered, and F represents the case where the final result where the two-way interaction effects were considered on the basis of the existence of two-way interaction terms identified in IE. IE gives the result of an intervening calculation step for identifying those of interaction terms with any statistical significance ($p<0.5$).

Table 5-1(a) Summary of MLR regression results (without factor analysis): cases identified for interaction effects in conjunction with Table 5-1(b)

Regression with independent variables interaction	AI Companies	Biotech Companies	Power plant Companies	All Companies
Rate of sales increase	5	3	5	1
Rate of sales increase per employee	1	2	5	2
Profitability	5	1	6	3
Profitability per employee	1	2	6	2
Ratio of R&D expenditure to sales	5	3	5	2
Ratio of R&D expenditure to sales per employee	2	2	3	2

Table 5-1(b) Summary of MLR regression results (without factor analysis): cases identified to identify the validity of interaction effects

	M	IE	F	
Case 1	O	×		B
Case 2	O	O	O	BA
Case 3	O	O	×	B
Case 4	×	O	O	BA
Case 5	×	×		B
Case 6	×	O	×	B

As shown in this table, three cases were observed in the AI field which are related to the hypothesis 1-a and 1-c. That is, it was found that there exists a positive (+) effect of the number of patents registered per employee on the ratio of sales increase per employee, profitability per employee, and the ratio of R&D expenditure to sales per employee with statistical significance. Also, it is worthwhile to note that considering the main effects was enough in determining the effect of patent indices on business parameters without the inclusion of two-way interaction terms. It was observed that the involvement of two-way interaction terms made little difference albeit for increasing the complexity of the MLR analysis. As shown in Table 4-8 (AI case), the introduction of interaction effects gave only a slight improvement of the R-squared value from 0.988 to 0.9907.

In the cases of Biotech, all six cases have generated results of statistical significance with the involvement of only the main effects. The results also showed the presence of a correlation of patent indices (except percentage of accepted patents) with business performance indicators in compliance with hypothesis 1-a. In addition, the results showed that one patent index (number of patents registered per employee) is negatively correlated with a number of business performance indicators (rate of sales increase, ratio of R&D expenditure to sales per employee) whereas those corresponding cases in AI showed positive correlations between them. As aforementioned, this negates hypothesis 1-b.

As compared to the cases of AI and Biotech, for the Power plant field, there was only one case with statistical significance. This case showed that one patent index (patent registration ratio) has a

negative (-) effect on the business performance indicator, ratio of R&D to sales per employee. This is in compliance with hypothesis 1-a. In addition, the involvement of two-way interactions made no difference in the final outcome where the interaction effects produced no results of statistical significance.

When all companies are considered, all six cases showed statistically significant results with the inclusion of only the main effects as given in Table 5-1. As aforementioned, when all companies are considered together, the prevailing effect of a field (or two fields) is sustained even after all companies are considered together, and the blending of the remaining dataset was not enough to overcome the effect carried over.

The MLR results given in Tables 4-6, 4-12, and 4-19 indicate the existence of a positive correlation between the number of patents registered per employee and the profitability per employee for the corresponding cases in AI, Biotech and all companies, upholding hypothesis 1-d. In addition, by examining the MLR results of Tables 4-5, 4-10, and 4-17 along with Tables 4-8, 4-14, and 4-21, it is readily shown that the number of patents registered per employee is correlated with the rate of sales increase per employee as well the ratio of R&D expenditure to sales per employee. However, they don't move in tandem; that is, the AI case showed a positive correlation in both situations while the rest demonstrated a negative correlation for the corresponding situation. This negates hypothesis 2-a.

Table 5-2 Results of the Hypothesis tested

Hypothesis		Variable			
Main	Sub	Independent	Dependent	Results	Remarks
H1	H1-a			Accepted	
	H1-b	Patent	Business	Rejected	
	H1-c	Indices	Performance	Accepted	AI
	H1-d	(5 entries)	Indicators	Accepted	AI, Bio, All
H2	H2-a		(6 entries)	Rejected	

Table 5-2 summarizes the validity of the hypotheses developed in Chapter III based upon the MLR

analysis discussed above without factor analysis on patent indices.

3. Multiple Linear Regressions (MLR) with Factor Analysis

It is worthwhile to note that, as in the corresponding cases without factor analysis, the response variables were again strongly affected by the main effects. This was also observed for the cases where all companies were considered together. Especially, in the AI cases, it was observed that there exists a close similarity between the corresponding cases in such a way that the response variables (business parameters) are correlated with the explanatory variables (patent indices) from the perspective of involving the main effects to produce results of statistical significance. In comparison, the Biotech cases showed no correlation results of statistical significance, which is totally different from those cases without factor analysis. It appears that the factored patent indices fail to carry sufficient information to be correlated with a business performance indicator by the MLR analysis as the factored patent indices are represented by a single number, called a "factor score."

More results are given in Appendix C.

Table 5-3 Summary of MLR regression results (with factor analysis)

Regression with factor scores interaction	AI Companies	Biotech Companies	Power plant Companies	All Companies
Rate of sales increase	5	4	5	2
Rate of sales increase per employee	3	4	5	2
Profitability	5	4	5	4
Profitability per employee	2	4	4	4
Ratio of R&D expenditure to sales	5	4	5	2
Ratio of R&D expenditure to sales per employee	2	4	1	2

4. Limitations of the Research

As the sample size is not very large (30 per industry), the results for one industry have a relatively strong influence on the regression results for the three industries combined (sample size of 90). That is, the association between a particular predictor variable and a response variable for one industry has an effect on the results for the sample comprising all three industries.

The data used for this research consists of data from 2013 to 2017; the results may have been affected by the differences in technical cycle time (TCT) between industries.

The most difficult part of this work was obtaining the relevant datasets. Especially, getting access to any materials or DB in this regard imposed a great difficulty as the bulk of information related to the business performance of firms were very limited. This acted as a kind of predicament in establishing a sound construct for the analysis of this work. Furthermore, the present analysis has extensively relied on p- and R-squared values in assessing the validity of the statistical outcome and it might be desirable to introduce additional means of investigation to consolidate whatever was found throughout this study, if applicable.

There may have been some variables that should have been considered along with the patent indices in addition to those examined in this work to promote the research's validity such as the TCT (technology cycle time), as well as some measure of the innovativeness of patented technologies, which could perhaps play somewhat important roles in conjunction with the patent indices applied in the MLR analysis. In addition, if possible, the merchantability of patented technology in terms of dollars and cents, as well as a quantifiable measure to assess the influence of time-lag in patent proceedings (in relation to business performance) are additional factors that could be considered along with the patent indices involved in the present work. The former will allow for a meaningful metric to assess the potential and cost-effectiveness of a patented technology. Meanwhile, the latter will provide some information concerning the appraisal of technologies under patent proceedings in conjunction with the TCT. Especially, this would allow for its inclusion in the present work, which was carried out using data from over a span of 5 years.

Furthermore, as witnessed in this work, the inclusion of two-way interaction terms made some difference in the final outcome of the statistical analysis, although those results seem to draw away from the original research model. This phenomenon might be implicating something in relation to the extra variables that could be accounted for in the analysis.

If any of these were to be included in any way as part of the independent variables, the internal validity of the present work would have become enhanced by removing some potential confounding variables.

The samples in this work were taken from companies with a higher number of patents than firms in general; therefore, this work's external validity is compromised as it cannot be said that these results are applicable to firms with an average or lower amount of patent activity.

As for construct validity, however, it can be said that the variables chosen in this work are reasonable measures for patent activity and business performance. In addition, if factors such as the applicability of patent technologies, technological similarity between patents, and potential spillovers could be put into measurable forms and included in the analysis, this would also have improved the validity of this work.

Additionally, for future work, it may be conceivable to develop further improved hypotheses to deliver a more persuasive picture in conjunction with what's been sought after in this work.

VI. Conclusions

The relationship between patent activities and business performance was investigated for three different fields of industry (AI, Biotech and Power plant). Linear as well as multiple linear regressions (MLR) were carried out to identify the significance of the correlation between various patent indices and measurable indicators (parameters) of business performance. Thirty companies were selected in each field for statistical examination, whose selection was based on the order of total number of patent applications filed during the period from 2013 to 2017 as found in USPTO (United States Patent and Trademark Office). Five patent indices were selected to measure patent activity and used as independent variables; patent application ratio, patent registration ratio, percentage of accepted patents, number of patent applications per employee and number of patent registrations per employee. Meanwhile, business performance was dealt with by using three categorical indices as dependent variables; the rate of sales increase (per employee), the profitability (per employee) and the ratio of R&D expenditure to sales. In addition, factor analysis was applied to the independent variables (patent activities) to identify and group whichever ones had a high correlation among themselves in conjunction with performing the MLR.

Overall, the following could be concluded from the findings of the present research.

First, it deems the results of the linear regressions can be used as reliable indicators to predict the outcome of the MLR regressions as one can envision the effect of an independent variable on a dependent variable. When examining the AI cases, the ones with low p-values (~0) also gave meaningful results in the MLR. That is, the ratio of sales increase per employee, profitability per employee, and the ratio of R&D expenditure to sales per employee showed a dependency on the number of patents registered per employee with statistical significance ($p < 0.5$), supporting hypotheses 1-a and 1-c.

Second, the MLR regressions provided detailed statistical information on the relationship between each patent index and the business performance indicators all together, and, at the same time, to identify one factor's relationship with the response variable as compared to the others. When only

the main effects were considered, three cases for the AI industry, six cases for the Biotech industry, and one case for the Power plant industry demonstrated the existence of a meaningful correlation between the patent activities and the responsive variables associated with business performance.

When the interaction effects among patent indices were considered, many cases displayed an improvement in both p and R-squared values. Especially, in some cases, the introduction of two-way interaction terms consolidated the sound results already produced by considering only the main effects. This, however, tends to detract from the original research model in most cases and increase the complexity of the MLR analysis.

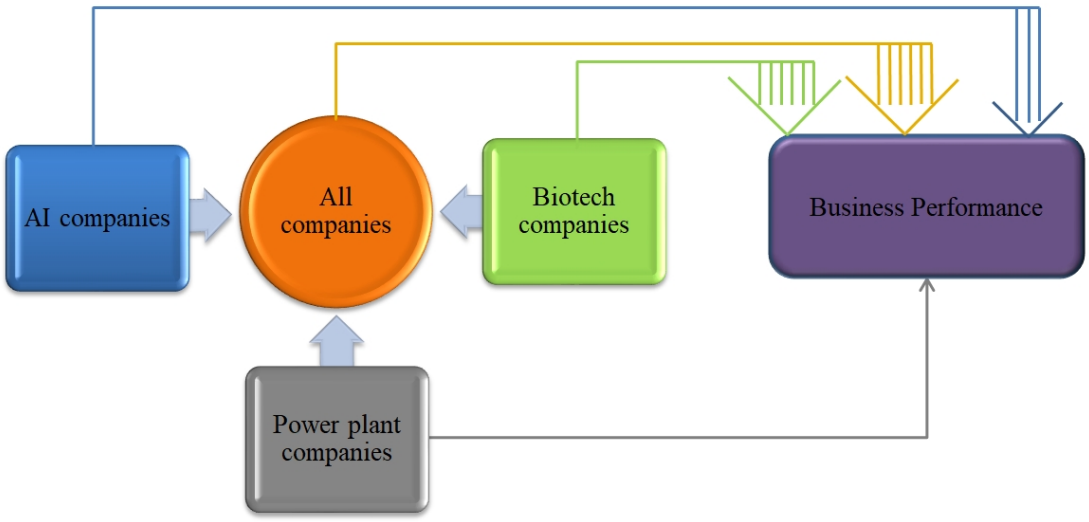

Fig. 6-1 The effect of patent activity on business performance in different fields

Third, the MLR results with factored predictor variables provided a means to measure the effect of two-way interaction terms from qualitative perspectives. For AI, the grouping of patent indices by factor analysis had little effect on the response variables associated with business performance. The inclusion of the main effects was enough in the MLR analysis. This was also sustained for the Power plant industry. The Biotech cases, however, showed a different picture as those cases of any statistical significance with the inclusion of interaction effects were not observed in the MLR analysis. This clearly manifests the significance of the interrelation between those predictor variables

included in different grouping variables, which is blocked by the grouping of predictor variables by factor analysis.

Fourth, when all companies were considered together as one large sample, it appears that the prevailing effect of a predictor variable (patent index) on the response variable (measure of business performance) is reflected also in the results of linear regression as well as MLR analysis.

This research provides useful referential information to any individual (entrepreneurs, practitioners, etc.) who aims to deduce whether an industry's characteristics in relation to business performance would be similar to the AI, Biotech, or Power plant industries. This is very important as the patent strategy in link with business planning should be different from field to field and it is imperative to reflect the distinct features of the technologies associated with each field.

Concerning technologies associated with AI, it might not be practical to proceed with the business until the stage where the technologies actually get registered and exclusive rights are legally obtained to release them into the market. Although both legal procedures of patent application and patent registration are important (as indicated by the results of this work), the former might be enough to function in the relevant market considering this field's rather short technology cycle time (TCT). As a matter of fact, the timeline for patent registration tends to be longer than the TCT. Merely filing for patent applications might be an effective strategy which could both save time and expenses in performing any business activities associated with technologies that are worthwhile to protect but short-lived.

In comparison, it is crucial to secure exclusive rights in the Biotech field as technologies in this industry are, more or less, directly involved with the development and production of new products to enter the market. In addition, as the TCT of Biotech is generally much longer than that of AI (>> 5 years), it is practically important to exclude competitors from getting any benefits from exploiting similar technologies of any kind. This would preclude the possibility of a higher financial and technical market risk for a firm when it is in the stage of developing and releasing new products that are based off of new technologies.

In the field of heavy industry such as the Power plant industry, the patent strategy should be different from those of AI and Biotech and it might be practical to just file for patent applications for the purpose of warding off any imitation efforts by potential competitors (This action will block the efforts of competitors trying to secure the exclusive rights for a technology as it is very unlikely to be considered over the prior art.). This is not due to the TCT as was the case with AI. It may actually be a more realistic approach considering the characteristics of the Power plant industry, which generally deals with heavy and bulky machineries or equipment composed of millions of components involving a host of relevant technologies. Unless it deems really necessary to protect a technology by means of the patent system (as observed for Biotech), the strategic option of merely filing for patent application would be desirable for the sake of cost-effectiveness in the long run. In addition, many companies in this field tend to rely on the corporation's knowhow (tacit knowledge), which has not been disclosed by patent applications, to a great degree.

All in all, by exploring the results of this work, one would be able to get some idea about the industry and how the role of patents differs according to the business field, and such knowledge would help think up measures for dealing with technological planning and potential issues that could come up in a real world situation while doing business, especially as there is severe technical competition with high risks and uncertainty in many cases.

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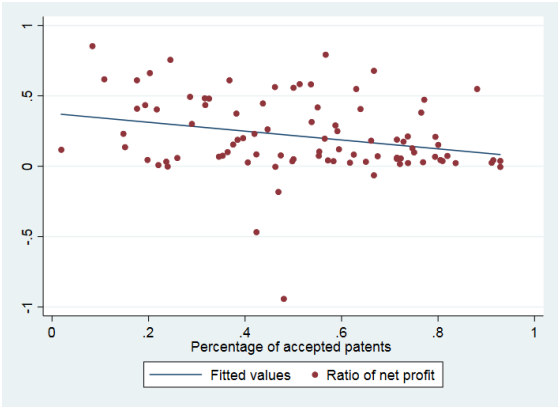
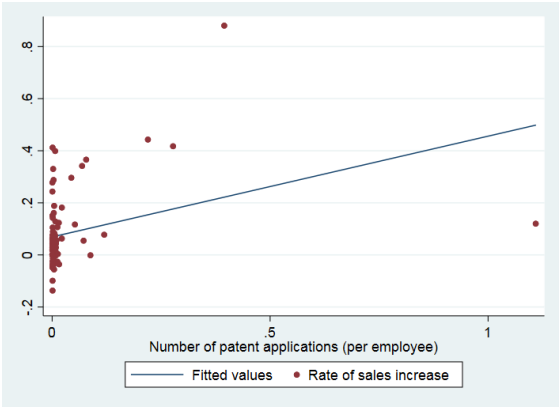
Appendix

A. Linear Regression Results



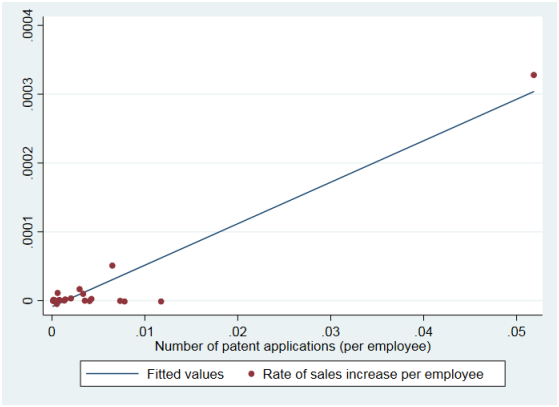
All companies; p-value = 0.0123

Fig. A-1 Percentage of accepted patents vs Profitability

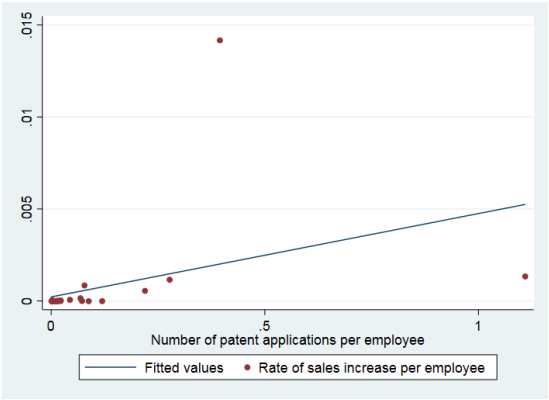


All companies; p-value = 0.0011

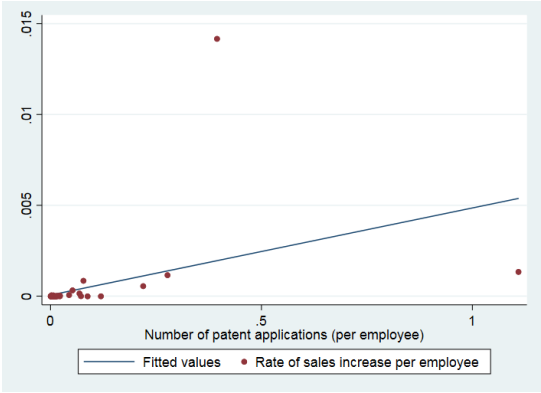
Fig. A-2 Number of patent applications per employee vs Rate of sales increase



(a) AI companies; p-value=0.0000

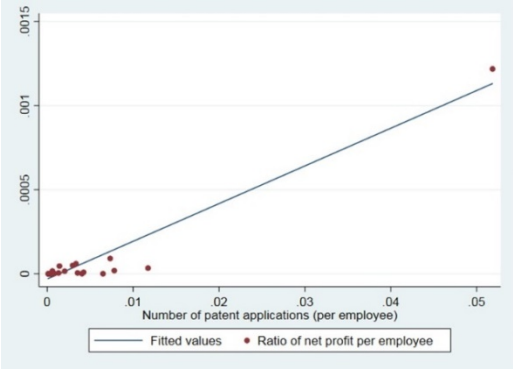


(b) Biotech companies; p-value = 0.0415

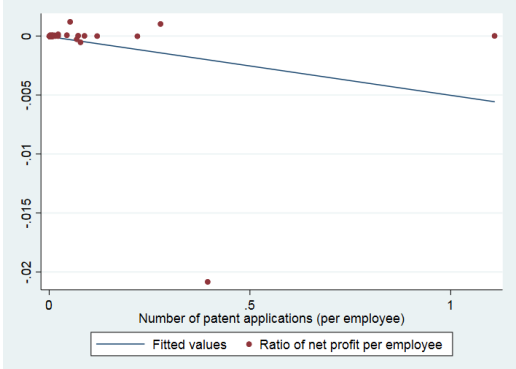


(c) All companies; p-value = 0.0001

Fig. A-3 Number of patent applications per employee vs Rate of sales increase per employee

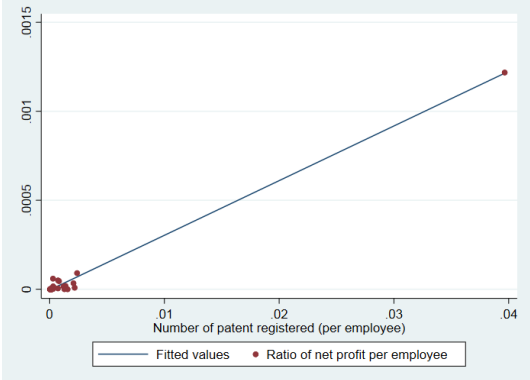


(a) AI companies; p-value = 0.0000



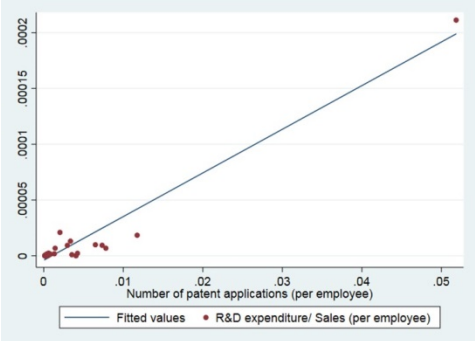
(b) All companies; p-value = 0.0056

Fig. A-4 Number of patent applications per employee vs Profitability per employee

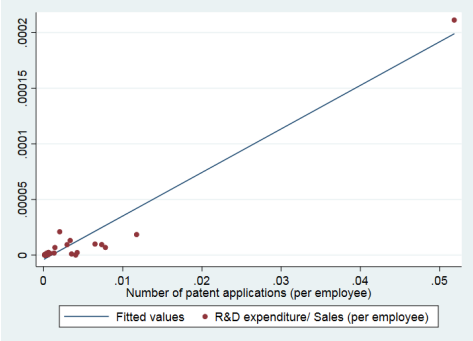


AI companies; p-value=0.0000

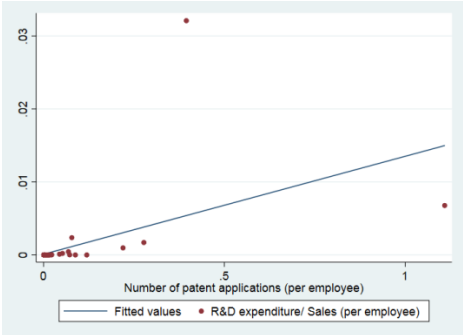
Fig. A-5 Number of patents registered per employee vs Profitability per employee



(a) AI companies; p-value=0

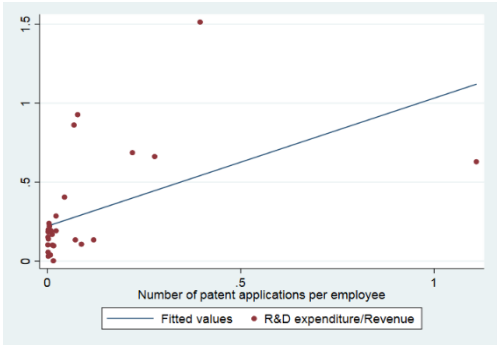


(b) Biotech companies; p-value = 0.0091

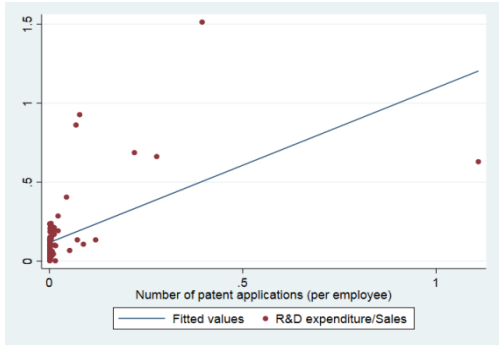


(c) All companies; p-value = 0.0000

Fig. A-6 Number of patent applications per employee vs Ratio of R&D expenditure to sales per employee

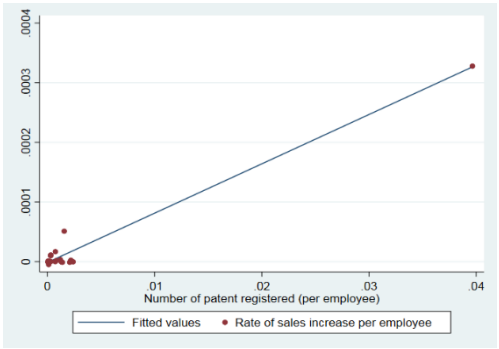


(a) Biotech Companies; p-Value = 0.0040

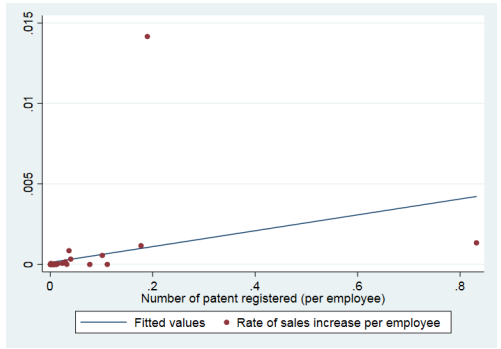


(b) All companies; p-value = 0.0000

Fig. A-7 Number of patent applications per employee vs Ratio of R&D expenditure to sales

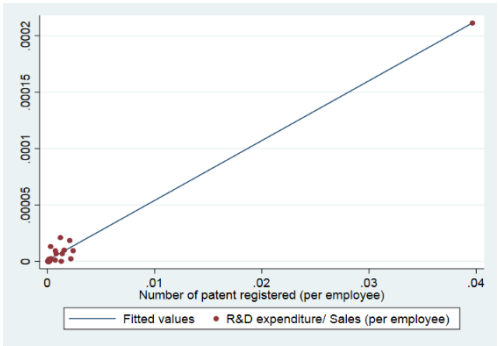


(a) AI companies; p-value = 0.0000

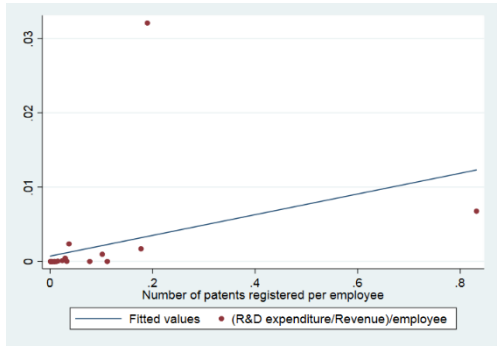


(b) All companies; p-values = 0.0037

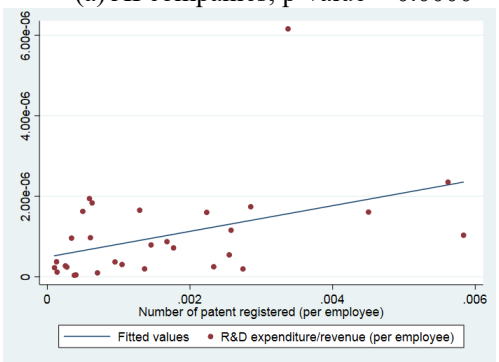
Fig. A-8 Number of patents registered per employee vs Rate of sales increase per employee



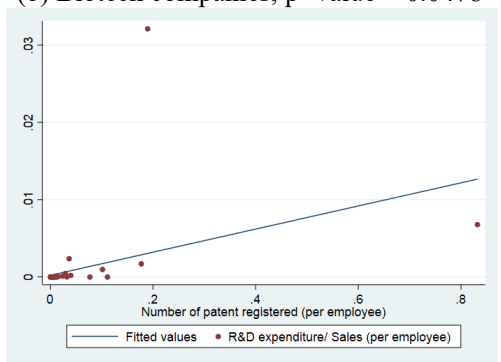
(a) AI companies; p-value = 0.0000



(b) Biotech companies; p- value = 0.0478



(c) AI Companies; p-value = 0.0197



(d) All companies; p-value = 0.0001

Fig. A-9 Number of patents registered per employee vs Ratio of R&D expenditure to sales per employee

B. Multilinear Regression Results (MLR)

Table B-1 Rate of sales increase (AI)

Rate of sales increase (Case 5)			
Description	Without Interaction		
	Coefficients	p-value	S.E of Regression
Patent Application Ratio	-3.616041	0.143	2.387485
Patent Registration Ratio	3.031792	0.183	2.20951
Percentage of Accepted Patents	-0.0343364	0.849	0.1778556
Number of Patent Applications per Employee	1.02E+01	0.453	13.39769
Number of Patents Registered per Employee	-12.62963	0.494	18.19341
_cons	0.0927411	0.217	0.0731377
Number of Observations	30		
Sum squared resid	0.43527193		
R-Squared	0.1424		
Adjusted R-squared	-0.0363		
Root MSE	0.13467		
p-value(F)	0.5626		

Table B-2 Rate of sales increase per employee (AI)

Rate of sales increase per employee (Case 1)			
Description	Without Interaction		
	Coefficients	p-value	S.E of Regression
Patent Application Ratio	-0.0000351	0.853	0.0001873
Patent Registration Ratio	0.000000834	0.996	0.0001734
Percentage of Accepted Patents	-0.00000893	0.528	0.000014
Number of Patent Applications per Employee	-9.18E-04	0.391	0.0010511
Number of Patents Registered per Employee	0.0095397	0.000	0.0014274
_cons	0.00000405	0.487	0.00000574
Number of Observations	30		
Sum squared resid	2.6794E-09		
R-Squared	0.9745		
Adjusted R-squared	0.9691		
Root MSE	0.000011		
p-value(F)	0.0000		

Table B-3 Profitability (AI)

Profitability (Case 5)			
Description	Without Interaction		
	Coefficients	p-value	S.E of Regression
Patent Application Ratio	0.9368107	0.85	4.895285
Patent Registration Ratio	-0.3746638	0.935	4.530368
Percentage of Accepted Patents	-0.138833	0.707	0.3646741
Number of Patent Applications per Employee	3.07E+01	0.276	27.47054
Number of Patents Registered per Employee	-35.42862	0.352	37.30366
_cons	0.3190563	0.044	0.149961
Number of Observations	30		
Sum squared resid	1.82993419		
R-Squared	0.1413		
Adjusted R-squared	-0.0376		
Root MSE	0.27613		
p-value(F)	0.5672		

Table B-4 Profitability per employee (AI)

Profitability per employee (Case 1)			
Description	Without Interaction		
	Coefficients	p-value	S.E of Regression
Patent Application Ratio	0.000288	0.405	0.0003398
Patent Registration Ratio	-0.0003725	0.248	0.0003145
Percentage of Accepted Patents	-0.00000979	0.702	0.0000253
Number of Patent Applications per Employee	-3.38E-03	0.089	0.0019069
Number of Patents Registered per Employee	0.0352545	0.000	0.0025894
_cons	0.00000654	0.536	0.0000104
Number of Observations	30		
Sum squared resid	8.8174E-09		
R-Squared	0.9938		
Adjusted R-squared	0.9925		
Root MSE	0.000019		
p-value(F)	0.0000		

Table B-5 Ratio of R&D expenditure to sale (AI)

Ratio of R&D expenditure to sales (Case 5)			
Description	Without Interaction		
	Coefficients	p-value	S.E of Regression
Patent Application Ratio	0.68334	0.578	1.21007
Patent Registration Ratio	-0.7187533	0.527	1.119865
Percentage of Accepted Patents	0.0072436	0.937	0.0901441
Number of Patent Applications per Employee	1.12E+01	0.113	6.790466
Number of Patents Registered per Employee	-15.12277	0.114	9.221124
_cons	0.0913811	0.021	0.037069
Number of Observations	30		
Sum squared resid	0.111815049		
R-Squared	0.1832		
Adjusted R-squared	0.0131		
Root MSE	0.06826		
p-value(F)	0.398		

Table B-6 Ratio of R&D expenditure to sales per employee (AI)

Ratio of R&D expenditure to sales per employee (Case 2)						
Description	Without Interaction			With Interaction		
	Coefficients	p-value	S.E of Regression	Coefficients	p-value	S.E of Regression
Patent Application Ratio	0.000064	0.398	0.0000743	0.0000599	0.45	0.0000779
Patent Registration Ratio	-0.0000857	0.225	0.0000688	-0.0000768	0.31	0.0000739
Percentage of Accepted Patents	0.00000349	0.534	0.00000554	0.00000141	0.777	0.00000493
Number of Patent Applications per Employee	0.0004384	0.304	0.000417	0.0041929	0.005	0.0013524
Number of Patents Registered per Employee	0.0047112	0.000	0.0005663	-0.0206869	0.025	0.0086282
ai1						
ai2						
ai3				0.0395098	0.007	0.0134042
ai4				-0.1868032	0.034	0.0824563
ai5						
ai6						
ai7						
ai8						
ai9						
ai10						
_cons	-1.38E-07	0.952	0.00000228	-2.28E-07	0.911	0.00000203
Number of Observations	30			30		
Sum squared resid	4.2169E-10			2.9966E-10		
R-Squared	0.9901			0.993		
Adjusted R-squared	0.988			0.9907		
Root MSE	0.0000042			0.0000037		
p-value(F)	0.0000			0.0000		

Table B-7 Rate of sales increase (Biotech)

Rate of sales increase (Case 3)			
Description	Without Interaction		
	Coefficients	p-value	S.E of Regression
Patent Application Ratio	-5.090797	0.035	2.273762
Patent Registration Ratio	3.434153	0.047	1.642348
Percentage of Accepted Patents	-0.2846021	0.176	0.2039517
Number of Patent Applications per Employee	5.18E+00	0.000	0.6159623
Number of Patents Registered per Employee	-6.765492	0.000	0.8572694
_cons	0.2638593	0.037	0.1197856
Number of Observations	30		
Sum squared resid	0.23269042		
R-Squared	0.7993		
Adjusted R-squared	0.7575		
Root MSE	0.09847		
p-value(F)	0.0000		

Table B-8 Rate of sales increase per employee (Biotech)

Rate of sales increase per employee (Case 2)						
Description	Without Interaction			With Interaction		
	Coefficients	p-value	S.E of Regression	Coefficients	p-value	S.E of Regression
Patent Application Ratio	-0.0440977	0.225	0.0354041	-0.0664889	0.113	0.0399308
Patent Registration Ratio	0.0323652	0.218	0.0255726	0.0894717	0.039	0.0401758
Percentage of Accepted Patents	-0.0018603	0.563	0.0031757	-0.0026544	0.202	0.0020044
Number of Patent Applications per Employee	0.0652808	0.000	0.009591	-0.7622571	0.000	0.1440018
Number of Patents Registered per Employee	-0.0847296	0.000	0.0133483	1.155693	0.000	0.1928623
ai1						
ai2				32.45923	0.002	9.127575
ai3				-2.467339	0.000	0.3934796
ai4				0.087573	0.000	0.0152937
ai5						
ai6						
ai7				21.42666	0.005	6.756756
ai8						
ai9				-42.66788	0.003	12.58363
ai10				1.663532	0.000	0.3021723
_cons	1.01E-03	0.593	0.0018651	1.22E-03	0.28	0.0010921
Number of Observations	30			30		
Sum squared resid	5.64E-05			3.32E-06		
R-Squared	0.7089			0.9821		
Adjusted R-squared	0.6483			0.9712		
Root MSE	0.00153			0.00044		
p-value(F)	0.0000			0.0000		

Table B-9 Profitability (Biotech)

Profitability (Case 1)			
Description	Without Interaction		
	Coefficients	p-value	S.E of Regression
Patent Application Ratio	5.605475	0.313	5.434165
Patent Registration Ratio	-3.845715	0.337	3.925119
Percentage of Accepted Patents	0.6377124	0.203	0.4874332
Number of Patent Applications per Employee	-6.95E+00	0.000	1.472115
Number of Patents Registered per Employee	8.921947	0.000	2.048826
_cons	-0.047425	0.87	0.2862809
Number of Observations	30		
Sum squared resid	1.32908872		
R-Squared	0.5779		
Adjusted R-squared	0.49		
Root MSE	0.23533		
p-value(F)	0.0006		

Table B-10 Profitability per employee (Biotech)

Profitability per employee (Case 2)						
Description	Without Interaction			With Interaction		
	Coefficients	p-value	S.E of Regression	Coefficients	p-value	S.E of Regression
Patent Application Ratio	0.0669617	0.266	0.0588474	0.0978418	0.175	0.0693263
Patent Registration Ratio	-0.0503306	0.248	0.0425057	-0.1367019	0.066	0.0697517
Percentage of Accepted Patents	0.0034893	0.515	0.0052785	0.0037812	0.292	0.00348
Number of Patent Applications per Employee	-0.0934702	0.000	0.0159418	1.157497	0.000	0.2500103
Number of Patents Registered per Employee	0.1236194	0.000	0.0221871	-1.812532	0.000	0.33484
ai1						
ai2				-48.89574	0.006	15.84694
ai3				3.814101	0.000	0.6831438
ai4				-0.1581381	0.000	0.0265524
ai5						
ai6						
ai7				-32.17791	0.013	11.73082
ai8						
ai9				64.15963	0.009	21.8472
ai10				-2.487012	0.000	0.5246198
_cons	-1.78E-03	0.572	0.0031002	-1.67E-03	0.391	0.0018961
Number of Observations	30			30		
Sum squared resid	1.56E-04			1.04E-05		
R-Squared	0.6305			0.9752		
Adjusted R-squared	0.5535			0.9601		
Root MSE	0.00255			0.00076		
p-value(F)	0.0001			0.0000		

Table B-11 Ratio of R&D expenditure to sales (Biotech)

Ratio of R&D expenditure to sales (Case 3)			
Description	Without Interaction		
	Coefficients	p-value	S.E of Regression
Patent Application Ratio	-6.335762	0.123	3.966079
Patent Registration Ratio	4.339237	0.143	2.864715
Percentage of Accepted Patents	-0.2731155	0.45	0.355749
Number of Patent Applications per Employee	8.35E+00	0.000	1.074411
Number of Patents Registered per Employee	-10.51592	0.000	1.495318
_cons	0.3593922	0.098	0.2089397
Number of Observations	30		
Sum squared resid	0.707964003		
R-Squared	0.7887		
Adjusted R-squared	0.7447		
Root MSE	0.17175		
p-value(F)	0.0000		

Table B-12 Ratio of R&D expenditure to sales per employee (Biotech)

Ratio of R&D expenditure to sales per employee (Case 2)						
Description	Without Interaction			With Interaction		
	Coefficients	p-value	S.E of Regression	Coefficients	p-value	S.E of Regression
Patent Application Ratio	-0.0987486	0.238	0.0816522	0.1175787	0.075	0.0624035
Patent Registration Ratio	0.0721686	0.233	0.0589777	-0.0522333	0.469	0.0706811
Percentage of Accepted Patents	-0.0046333	0.533	0.007324	0.0019911	0.7	0.0050898
Number of Patent Applications per Employee	0.1413128	0.000	0.0221196	-0.787919	0.01	0.2739608
Number of Patents Registered per Employee	-0.1788411	0.000	0.0307851	1.738835	0.002	0.4837998
ai1						
ai2						
ai3				-3.406897	0.001	0.8865906
ai4				0.209826	0.000	0.0445119
ai5						
ai6						
ai7				-5.883163	0.000	0.7886241
ai8						
ai9				4.676737	0.000	0.8186225
ai10				1.638375	0.004	0.4972943
_cons	2.44E-03	0.576	0.0043016	-2.06E-03	0.45	0.0026678
Number of Observations	30			30		
Sum squared resid	3.00E-04			3.11E-05		
R-Squared	0.7061			0.9696		
Adjusted R-squared	0.6449			0.9536		
Root MSE	0.00354			0.00128		
p-value(F)	0.0000			0.0000		

Table B-13 Rate of sales increase (Power plant)

Rate of sales increase (Case 5)			
Description	Without Interaction		
	Coefficients	p-value	S.E of Regression
Patent Application Ratio	-0.5662579	0.446	0.7304462
Patent Registration Ratio	0.4285753	0.628	0.8725179
Percentage of Accepted Patents	0.045955	0.668	0.1058273
Number of Patent Applications per Employee	2.53E+01	0.223	20.20437
Number of Patents Registered per Employee	-42.13329	0.204	32.2951
_cons	0.0070133	0.928	0.0766873
Number of Observations	30		
Sum squared resid	0.072289771		
R-Squared	0.086		
Adjusted R-squared	-0.1044		
Root MSE	0.05488		
p-value(F)	0.8079		

Table B-14 Rate of sales increase per employee (Power plant)

Rate of sales increase per employee (Case 5)			
Description	Without Interaction		
	Coefficients	p-value	S.E of Regression
Patent Application Ratio	-0.0000297	0.127	0.0000188
Patent Registration Ratio	0.0000225	0.327	0.0000225
Percentage of Accepted Patents	0.00000196	0.48	0.00000272
Number of Patent Applications per Employee	1.32E-03	0.018	0.00052
Number of Patents Registered per Employee	-0.0019965	0.024	0.0008312
_cons	-0.00000074	0.711	0.00000197
Number of Observations	30		
Sum squared resid	4.7886E-11		
R-Squared	0.2625		
Adjusted R-squared	0.1088		
Root MSE	0.0000014		
p-value(F)	0.1711		

Table B-15 Profitability (Power plant)

Profitability (Case 6)			
Description	Without Interaction		
	Coefficients	p-value	S.E of Regression
Patent Application Ratio	0.6294259	0.439	0.7993896
Patent Registration Ratio	-0.6053804	0.532	0.9548709
Percentage of Accepted Patents	-0.1144465	0.333	0.1158158
Number of Patent Applications per Employee	-2.67E+01	0.239	22.11137
Number of Patents Registered per Employee	51.25643	0.16	35.34329
_cons	0.1312107	0.131	0.0839254
Number of Observations	30		
Sum squared resid	0.086579969		
R-Squared	0.144		
Adjusted R-squared	-0.0343		
Root MSE	0.06006		
p-value(F)	0.5557		

Table B-16 Profitability per employee (Power plant)

Profitability per employee (Case 6)			
Description	Without Interaction		
	Coefficients	p-value	S.E of Regression
Patent Application Ratio	0.0000903	0.136	0.0000585
Patent Registration Ratio	-0.0001389	0.058	0.0000699
Percentage of Accepted Patents	2.34E-08	0.998	0.00000847
Number of Patent Applications per Employee	-2.10E-03	0.207	0.0016177
Number of Patents Registered per Employee	0.0048033	0.076	0.0025858
_cons	0.00000123	0.843	0.00000614
Number of Observations	30		
Sum squared resid	4.6345E-10		
R-Squared	0.2845		
Adjusted R-squared	0.1354		
Root MSE	0.0000044		
p-value(F)	0.1303		

Table B-17 Ratio of R&D expenditure to sales (Power plant)

Ratio of R&D expenditure to sales (Case 5)			
Description	Without Interaction		
	Coefficients	p-value	S.E of Regression
Patent Application Ratio	-0.2279049	0.49	0.3247906
Patent Registration Ratio	0.2506228	0.524	0.3879624
Percentage of Accepted Patents	-0.0065866	0.89	0.0470558
Number of Patent Applications per Employee	3.23E+00	0.722	8.98381
Number of Patents Registered per Employee	-6.069245	0.676	14.35992
_cons	0.0507699	0.15	0.0340988
Number of Observations	30		
Sum squared resid	0.014292473		
R-Squared	0.0219		
Adjusted R-squared	-0.1818		
Root MSE	0.0244		
p-value(F)	0.9896		

Table B-18 Ratio of R&D expenditure to sales per employee (Power plant)

Ratio of R&D expenditure to sales per employee (Case 3)			
Description	Without Interaction		
	Coefficients	p-value	S.E of Regression
Patent Application Ratio	0.0000175	0.184	0.0000128
Patent Registration Ratio	-0.0000361	0.027	0.0000153
Percentage of Accepted Patents	0.000000686	0.714	0.00000185
Number of Patent Applications per Employee	-2.15E-04	0.55	0.0003538
Number of Patents Registered per Employee	0.0008542	0.144	0.0005656
_cons	0.000000322	0.813	0.00000134
Number of Observations	30		
Sum squared resid	2.217E-11		
R-Squared	0.4562		
Adjusted R-squared	0.3429		
Root MSE	0.00000096		
p-value(F)	0.0085		

Table B-19 Rate of sales increase (All companies)

Rate of sales increase (Case 1)			
Description	Without Interaction		
	Coefficients	p-value	S.E of Regression
Patent Application Ratio	-2.62041	0.064	1.394163
Patent Registration Ratio	1.463218	0.21	1.159082
Percentage of Accepted Patents	-0.0409492	0.461	0.0552303
Number of Patent Applications per Employee	5.46E+00	0.000	0.5938859
Number of Patents Registered per Employee	-7.135073	0.000	0.8286443
_cons	0.0866389	0.008	0.032013
Number of Observations	90		
Sum squared resid	0.85594788		
R-Squared	0.5523		
Adjusted R-squared	0.5257		
Root MSE	0.10094		
p-value(F)	0.0000		

Table B-20 Rate of sales increase per employee (All companies)

Rate of sales increase per employee (Case 2)						
Description	Without Interaction			With Interaction		
	Coefficients	p-value	S.E of Regression	Coefficients	p-value	S.E of Regression
Patent Application Ratio	-0.0127575	0.285	0.0118498	-0.0982095	0.001	0.0285296
Patent Registration Ratio	0.0106297	0.284	0.0098517	0.169228	0.003	0.0544145
Percentage of Accepted Patents	0.0001636	0.728	0.0004694	-0.0003699	0.166	0.0002644
Number of Patent Applications per Employee	0.064379	0.000	0.0050478	-0.2659041	0.000	0.0641765
Number of Patents Registered per Employee	-0.0838981	0.000	0.0070431	0.3879916	0.000	0.0864373
ai1						
ai2				44.40794	0.000	7.362062
ai3				-0.9814121	0.000	0.1780719
ai4				0.0287027	0.000	0.0060268
ai5						
ai6						
ai7				29.46768	0.000	5.827738
ai8				-0.1107258	0.017	0.0454714
ai9				-56.28602	0.000	9.905648
ai10				0.7051472	0.000	0.1339076
_cons	-1.95E-04	0.477	0.0002721	1.78E-04	0.235	0.0001485
Number of Observations	90			90		
Sum squared resid	6.18E-05			1.03E-05		
R-Squared	0.6929			0.9488		
Adjusted R-squared	0.6746			0.9409		
Root MSE	0.00086			0.00037		
p-value(F)	0.0000			0.0000		

Table B-21 Profitability (All companies)

Profitability (Case 3)			
Description	Without Interaction		
	Coefficients	p-value	S.E of Regression
Patent Application Ratio	-0.4162806	0.896	3.175517
Patent Registration Ratio	1.971701	0.457	2.640068
Percentage of Accepted Patents	-0.4233329	0.001	0.1257994
Number of Patent Applications per Employee	-6.84E+00	0.000	1.352708
Number of Patents Registered per Employee	9.183826	0.000	1.887423
_cons	0.4454232	0	0.0729169
Number of Observations	90		
Sum squared resid	4.44067848		
R-Squared	0.3171		
Adjusted R-squared	0.2765		
Root MSE	0.22992		
p-value(F)	0.0000		

Table B-22 Profitability per employee (All companies)

Profitability per employee (Case 2)						
	Without Interaction			With Interaction		
Description	Coefficients	p-value	S.E of Regression	Coefficients	p-value	S.E of Regression
Patent Application Ratio	0.0193262	0.327	0.0196185	0.1464946	0.002	0.0456633
Patent Registration Ratio	-0.0175649	0.285	0.0163105	-0.2521593	0.005	0.0870936
Percentage of Accepted Patents	-0.0000865	0.912	0.0007772	0.0005542	0.194	0.0004232
Number of Patent Applications per Employee	-0.0922941	0.000	0.0083571	0.4265503	0.000	0.1027182
Number of Patents Registered per Employee	0.1229204	0.000	0.0116606	-0.6906685	0.000	0.1383479
ai1						
ai2				-66.26188	0.000	11.7834
ai3				1.636311	0.000	0.2850143
ai4				-0.0736331	0.000	0.0096462
ai5						
ai6						
ai7				-43.75152	0.000	9.327629
ai8				0.1601397	0.031	0.0727796
ai9				83.66548	0.000	15.85456
ai10				-1.070316	0.000	0.2143267
_cons	2.62E-04	0.562	0.0004505	-2.75E-04	0.252	0.0002376
Number of Observations	90			90		
Sum squared resid	1.69E-04			2.64E-05		
R-Squared	0.6084			0.939		
Adjusted R-squared	0.5851			0.9295		
Root MSE	0.00142			0.00059		
p-value(F)	0.0000			0.0000		

Table B-23 Ratio of R&D expenditure to sales (All companies)

Ratio of R&D expenditure to sales (Case 2)						
Description	Without Interaction			With Interaction		
	Coefficients	p-value	S.E of Regression	Coefficients	p-value	S.E of Regression
Patent Application Ratio	-2.46844	0.112	1.539055	-1.694085	0.273	1.533796
Patent Registration Ratio	2.037679	0.115	1.279542	1.017317	0.442	1.318276
Percentage of Accepted Patents	-0.10598	0.086	0.0609703	-0.1058531	0.078	0.0593645
Number of Patent Applications per Employee	9.048471	0.000	0.6556069	7.728671	0.000	0.847471
Number of Patents Registered per Employee	-11.33257	0.000	0.9147633	-8.018474	0.000	1.659086
ai1						
ai2						
ai3						
ai4				-1.456803	0.02	0.6152953
ai5						
ai6						
ai7						
ai8						
ai9						
ai10						
_cons	1.50E-01	0	0.0353401	1.46E-01	0	0.0344542
Number of Observations	90			90		
Sum squared resid	1.04E+00			9.77E-01		
R-Squared	0.7678			0.7825		
Adjusted R-squared	0.7539			0.7667		
Root MSE	0.11144			0.1085		
p-value(F)	0.0000			0.0000		

Table B-24 Ratio of R&D expenditure to sales per employee (All companies)

Ratio of R&D expenditure to sales per employee (Case 2)						
Description	Without Interaction			With Interaction		
	Coefficients	p-value	S.E of Regression	Coefficients	p-value	S.E of Regression
Patent Application Ratio	-0.0264432	0.335	0.0272742	-0.2266248	0.001	0.0633792
Patent Registration Ratio	0.0211138	0.354	0.0226753	0.3948232	0.002	0.1208832
Percentage of Accepted Patents	0.0003064	0.777	0.0010805	-0.000822	0.166	0.0005873
Number of Patent Applications per Employee	0.1392942	0.000	0.0116183	-0.5823266	0.000	0.1425697
Number of Patents Registered per Employee	-0.1772037	0.000	0.0162109	0.8697075	0.000	0.1920226
ai1						
ai2				99.42748	0.000	16.35499
ai3				-2.190855	0.000	0.3955909
ai4				0.0780281	0.000	0.0133886
ai5						
ai6						
ai7				65.69161	0.000	12.94645
ai8				-0.2607383	0.012	0.1010158
ai9				-125.8089	0.000	22.00563
ai10				1.544603	0.000	0.2974787
_cons	-4.28E-04	0.496	0.0006263	3.97E-04	0.232	0.0003298
Number of Observations	90			90		
Sum squared resid	3.28E-04			5.08E-05		
R-Squared	0.6924			0.9523		
Adjusted R-squared	0.6741			0.9448		
Root MSE	0.00197			0.00081		
p-value(F)	0.0000			0.0000		

C. Multilinear Regression Results (MLR with Factored Patent Indices)

Table C-1 Rate of sales increase per employee (AI)

Rate of sales increase per employee (Case 3)			
Description	Without Interaction		
	Coefficients	p-value	S.E of Regression
AIP1	-0.00000424	0.076	0.0000023
AIP2	0.0000588	0.000	0.00000232
AIP3	0.00000864	0.001	0.00000232
_cons	1.41E-05	0	0.00000226
Number of Observations	30		
Sum squared resid	3.9751E-09		
R-Squared	0.9621		
Adjusted R-squared	0.9577		
Root MSE	0.000012		
p-value(F)	0.0000		

Table C-2 Profitability per employee (AI)

Profitability per employee (Case 2)						
Description	Without Interaction			With Interaction		
	Coefficients	p-value	S.E of Regression	Coefficients	p-value	S.E of Regression
AIP1	-0.0000147	0.022	0.000006	-9.10E-06	0.012	3.34E-06
AIP2	0.0002187	0.000	0.00000606	0.0001691	0.000	7.49E-06
AIP3	0.0000292	0.000	0.00000607	0.0000297	0.000	4.41E-06
ai1						
ai2				0.0000684	0.000	9.59E-06
ai3				-0.0000177	0.025	7.44E-06
_cons	5.35E-05	0	5.90E-06	0.0000533	0	3.19E-06
Number of Observations	30			30		
Sum squared resid	2.7173E-08			7.34E-09		
R-Squared	0.9808			0.9948		
Adjusted R-squared	0.9786			0.9938		
Root MSE	0.000032			1.70E-05		
p-value(F)	0.0000			0.0000		

Table C-3 Rate of R&D expenditure to sales per employee (AI)

Ratio of R&D expenditure to sales per employee (Case 2)						
Description	Without Interaction			With Interaction		
	Coefficients	p-value	S.E of Regression	Coefficients	p-value	S.E of Regression
AIP1	-0.00000282	0.004	0.000000908	-2.37E-06	0.005	7.64E-07
AIP2	0.000038	0.000	0.000000916	0.0000325	0.000	1.73E-06
AIP3	0.00000429	0.000	0.000000918	0.00000362	0.000	7.85E-07
ai1						
ai2				0.00000781	0.001	2.19E-06
ai3						
_cons	1.09E-05	0	8.92E-07	0.0000108	0	7.41E-07
Number of Observations	30			30		
Sum squared resid	6.21E-10			4.11E-10		
R-Squared	0.9854			0.9903		
Adjusted R-squared	0.9837			0.9888		
Root MSE	0.0000049			4.10E-06		
p-value(F)	0.0000			0.0000		

Table C-4 Rate of sales increase (Biotech)

Rate of sales increase (Case 4)						
Description	Without Interaction			With Interaction		
	Coefficients	p-value	S.E of Regression	Coefficients	p-value	S.E of Regression
BTP1	-0.0457607	0.222	0.036568	-2.33E-01	0.008	8.04E-02
BTP2	0.0560512	0.139	0.0367512	0.2220999	0.000	5.45E-02
BTP3	-0.0035411	0.924	0.0368226	-0.2096912	0.002	5.86E-02
ai1						
ai2				-0.6275612	0.001	0.1677102
ai3				0.1612382	0.007	0.054851
_cons	1.36E-01	0.001	0.0359501	0.13786	0	2.78E-02
Number of Observations	30			30		
Sum squared resid	1.01E+00			5.58E-01		
R-Squared	0.1305			0.5186		
Adjusted R-squared	0.0302			0.4183		
Root MSE	0.19691			1.52E-01		
p-value(F)	0.2952			0.0023		

Table C-5 Ratio of R&D expenditure to sales per employee (Power plant)

Ratio of R&D expenditure to sales per employee (Case 1)			
Description	Without Interaction		
	Coefficients	p-value	S.E of Regression
PPP1	-4.39E-07	0.025	0.000000184
PPP2	0.000000587	0.004	0.000000186
PPP3	2.86E-09	0.988	0.000000193
_cons	1.02E-06	0	0.000000181
Number of Observations	30		
Sum squared resid	2.5502E-11		
R-Squared	0.3744		
Adjusted R-squared	0.3022		
Root MSE	0.00000099		
p-value(F)	0.0061		

Table C-6 Rate of sales increase (All companies)

Rate of sales increase (Case 2)						
Description	Without Interaction			Without Interaction		
	Coefficients	p-value	S.E of Regression	Coefficients	p-value	S.E of Regression
P1	-0.024531	0.102	0.0148598	3.14E-02	0.08	1.77E-02
P2	0.0432362	0.005	0.0149337	0.0487257	0.000	1.34E-02
P3	-0.0064331	0.67	0.0150378	0.0009656	0.943	1.35E-02
ai1						
ai2				-0.2760183	0.000	0.0578524
ai3						
_cons	8.13E-02	0	0.0147768	0.0816007	0	1.32E-02
Number of Observations	90			90		
Sum squared resid	1.69E+00			1.33E+00		
R-Squared	0.116			0.3028		
Adjusted R-squared	0.0852			0.2699		
Root MSE	0.14018			1.25E-01		
p-value(F)	0.0137			0.0000		

Table C-7 Rate of sales increase per employee (All companies)

Rate of sales increase per employee (Case 2)						
Description	Without Interaction			Without Interaction		
	Coefficients	p-value	S.E of Regression	Coefficients	p-value	S.E of Regression
P1	-0.0000924	0.541	0.0001507	5.26E-04	0.000	1.25E-04
P2	0.0005408	0.001	0.0001514	0.0005798	0.000	9.00E-05
P3	-0.0001088	0.477	0.0001525	-0.0011468	0.000	2.05E-04
ai1						
ai2				-0.0050438	0.000	0.0004047
ai3				0.0003069	0.000	0.000049
_cons	2.10E-04	0.164	0.0001498	0.0002158	0.017	8.84E-05
Number of Observations	90			90		
Sum squared resid	1.74E-04			5.91E-05		
R-Squared	0.1368			0.7066		
Adjusted R-squared	0.1067			0.6891		
Root MSE	0.00142			8.40E-04		
p-value(F)	0.0053			0.0000		

Table C-8 Ratio of R&D expenditure to sales (All companies)

Ratio of R&D expenditure to sales (Case 2)						
Description	Without Interaction			Without Interaction		
	Coefficients	p-value	S.E of Regression	Coefficients	p-value	S.E of Regression
P1	-0.0154037	0.457	0.0206009	3.24E-02	0.131	2.12E-02
P2	0.1156375	0.000	0.0207035	0.1169253	0.000	1.52E-02
P3	-0.0226066	0.281	0.0208478	-0.1915523	0.000	3.48E-02
ai1						
ai2				-0.5475956	0.000	0.0685249
ai3				0.0480316	0.000	0.0082999
_cons	1.48E-01	0	2.05E-02	0.1486804	0	1.50E-02
Number of Observations		90			90	
Sum squared resid		3.25E+00			1.69E+00	
R-Squared		0.2768			0.6228	
Adjusted R-squared		0.2516			0.6004	
Root MSE		0.19435			1.42E-01	
p-value(F)		0.0000			0.0000	

Table C-9 Ratio of R&D expenditure to sales per employee (All companies)

Ratio of R&D expenditure to sales per employee(Case 2)						
Description	Without Interaction			Without Interaction		
	Coefficients	p-value	S.E of Regression	Coefficients	p-value	S.E of Regression
P1	-0.000215	0.518	0.0003312	1.13E-03	0.000	2.84E-04
P2	0.0015674	0.000	0.0003328	0.0016531	0.000	2.03E-04
P3	-0.0002439	0.469	0.0003351	-0.0024685	0.000	4.64E-04
ai1						
ai2				-0.0109299	0.000	0.0009148
ai3				0.0006585	0.000	0.0001108
_cons	5.00E-04	0.132	3.29E-04	0.0005128	0.012	2.00E-04
Number of Observations		90			90	
Sum squared resid		8.39E-04			3.02E-04	
R-Squared		0.2119			0.7165	
Adjusted R-squared		0.1844			0.6996	
Root MSE		0.00312			1.90E-03	
p-value(F)		0.0001			0.0000	